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CASE REPORT

CLINICAL CASE

What Knot to Do
Retrieval of a Kinked and Trapped Coronary Catheter

Shahbaz A. Malik, MD, Ganesh Gajanan, MD, Yiannis S. Chatzizisis, MD, PhD, Edward L. O’Leary, MD, MBA

ABSTRACT

Diagnostic coronary artery catheter knotting and kinking are uncommon but potentially catastrophic complications. Our case emphasizes the importance of avoiding this problem and provides recommendations for catheter retrieval in the unlikely event of this complication. To our knowledge, the technique used in our case has not been described before. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1657–61) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 76-year-old man was transferred to our institution with reports of shortness of breath and peripheral edema. Physical examination was pertinent for blood pressure of 159/70 mm Hg, heart rate of 71 beats/min, oxygen saturation of 91% on room air, regular cardiac rhythm, a mechanical click from a prosthetic heart valve, and intact distal pulses.

PAST MEDICAL HISTORY

The patient had undergone mechanical aortic valve replacement and had an implantable cardioverter-defibrillator.

DIFFERENTIAL DIAGNOSIS

Congestive heart failure and other noncardiac causes of dyspnea and peripheral edema were included in the differential diagnosis.

INVESTIGATIONS

Serial troponin levels were within the normal range. Echocardiography demonstrated a reduced left ventricular ejection fraction at 45%. He was referred for invasive coronary angiography (ICA) to rule out an ischemic cause for the new onset cardiomyopathy. ICA was performed through a right radial approach. A 5-F Judkins right 4 (JR4) diagnostic catheter (Merit Medical Systems, South Jordan, Utah) was advanced over a 0.035-inch guidewire into the ascending aorta. Multiple attempts were made to engage the right

LEARNING OBJECTIVES

• To understand the predisposing factors and mechanisms that lead to kinking and trapping of a coronary catheter, which is an uncommon, but potentially morbid complication of left heart catheterization.
• To discuss strategies to kinking and trapping of a coronary catheter, as well as percutaneous approaches to retrieve a kinked coronary catheter safely.

From the Cardiovascular Division, University of Nebraska Medical Center, Omaha, Nebraska. Dr. Chatzizisis has received speaker honoraria, advisory board fees, and a research grant from Boston Scientific; and has received a research grant from Medtronic. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose. The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors’ institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the JACC: Case Reports author instructions page.

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coronary artery without success because of severe tortuosity of the innominate artery (IA) and the takeoff of the coronary artery. We eventually lost the pressure waveform and, on troubleshooting, found that we could not aspirate or torque the catheter. A kink was noted in the middle portion of the catheter on fluoroscopy.

**MANAGEMENT**

Multiple attempts to release the kink were unsuccessful, such as gently torquing the catheter in the opposite direction and then trying to pass a 0.035-inch guidewire followed by a 0.014-inch coronary guidewire.

With conservative measures unable to resolve the kink and thus allow for withdrawal of the JR4 catheter, it was decided to attempt to retrieve it through the left common femoral artery (FA). This artery was accessed under ultrasound guidance. The access site was “pre-closed” using 2 Perclose Proglide sutures (Abbott, Abbott Park, Illinois) over a standard 0.035-inch guidewire. A 7-F sheath (Terumo, Tokyo, Japan) was placed. We then advanced a JR4 catheter from the left FA to the tortuous IA (Figure 1), over the same 0.035-inch guidewire, which was then exchanged for a Glidewire Advantage guidewire (Terumo). This was used to navigate the IA and then pass down into the right brachial artery. The femoral JR4 catheter was removed, leaving the Glidewire in place, and over this a Quick-Cross catheter (Philips, Amsterdam, the Netherlands) was passed into the right brachial artery. The Glidewire was exchanged for an Amplatz Super Stiff guidewire (Boston Scientific, Marlborough, Massachusetts), after which the Quick-Cross catheter was removed. At this point the left FA 7-F sheath was removed, leaving the Amplatz Super Stiff guidewire in place. Over this, a long, 80 cm × 14-F sheath (Cook Medical, Bloomington, Indiana) was gradually advanced from the left FA all the way to the IA. Using a sheath that had a diameter large enough to accommodate a catheter folded back on itself afforded both options of retrieving the trapped catheter through a snaring device through the sheath or en bloc while removing the large-bore sheath.

The kinked JR4 catheter was able to be advanced approximately 20 cm into the distal end of the 14-F sheath. We then advanced a standard 0.014-inch coronary guidewire from the hub of the 14-F sheath into the IA past the kinked catheter that now lay within the sheath. Over this guidewire, a 5-mm coronary noncompliant Trek balloon (Abbott) was delivered immediately adjacent to the JR4 catheter within the 14-F sheath, where it was inflated to rated burst pressure, thus trapping the JR4 catheter against the inner wall of the 14-F sheath (Figure 2).

The hub of the JR4 catheter, at the radial artery end, was now cut to allow the 14-F sheath with the JR4 catheter trapped within it, to be pulled from the left common FA, thus extracting the JR4 catheter from the body. The previously deployed Perclose Proglide sutures were immediately tightened to achieve hemostasis. To verify adequate hemostasis, contralateral access was obtained in the right FA, and

**FIGURE 1** Angiogram Demonstrating Trapped JR4 Catheter Within the Tortuous Innominate Artery

**FIGURE 2** Angiogram Showing Kinked Catheter Retrieval

The image shows our approach to retrieval of the kinked JR4 catheter by telescoping it into a retrograde 14-F sheath and stabilizing it in the sheath with a balloon.
ipsilateral iliofemoral angiography was performed. The patient tolerated the procedure well and had no apparent complications when he left the cardiac catheterization laboratory.

**DISCUSSION**

Catheter knotting during ICA is an uncommon but recognized complication, usually occurring during manipulations while intubating the right coronary artery (1). This has been reported to be related to higher torque buildup in the proximal portion of the catheter during manipulations, compared with the distal end, in the setting of vascular tortuosity (2). Indeed, this condition precipitated the situation in our case. Points to be kept in mind to help prevent this complication, as summarized in Table 1, include avoidance of torquing a catheter more than 180°, being mindful of vascular tortuosity if encountered, maintaining a guidewire through the catheter, and paying attention to situations where loss of torque is observed, pressure damping is noted, or an inability to aspirate the catheter occurs (3). Other elements to consider are the use of long sheaths if considerable vascular tortuosity is noted and that catheters smaller than 6-F are more prone to kinking.

Once a kink has occurred, techniques to deal with this are anecdotal, with a dearth of randomized data on this topic. A technique has been described whereby the proximal end of the knotted catheter is fixed by inflating a sphygmomanometer cuff in the ipsilateral brachial region, followed by gentle torque of the catheter in the opposite direction of the initial torque to untwist a kinked catheter (4). Another approach involves catching the tip of the kinked catheter by using an Amplatz Goose Neck Snare (Merit Medical Systems) to capture the distal tip of the kinked catheter, followed by unraveling of the knot (5). A similar approach, but with a slight modification, is the use of an EN Snare catheter (Merit Medical Systems) to catch the distal tip of the kinked catheter, followed by twisting of distal and proximal ends of the kinked catheter in opposite directions to unravel the knot (6). Another report detailed a kinked JL catheter in the brachial segment that was able to be retrieved by cutting the hub of the catheter and replacing the 6-F large bore sheath (7). All the techniques mentioned here are summarized in Table 2. To our knowledge, retrieval of a kinked catheter by using balloon-assisted trapping, as in our case, has not been reported before. Figure 3 is an algorithm showing factors predisposing to catheter kinking, ways to assess for it, conservative measures to address it, advanced percutaneous techniques for management that can be considered if conservative measures fail, and our strategy that can be used if other measures fall short.

**FOLLOW-UP**

The patient was medically managed with a plan to return in the future for ischemic evaluation.

**CONCLUSIONS**

As with most issues in the cardiac catheterization laboratory, preventing a complication is often much
easier than managing it. Care must be taken in all aspects while manipulating the catheter, especially within tortuous vasculature. Once the complication is suspected, recognizing it early is paramount; once it has occurred, tailoring retrieval to each individual case is prudent.

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KEY WORDS coronary angiography, kinked catheter, retrieval

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Cardiac Arrest in the Setting of Diffuse Coronary Ectasia
Perspectives on a Unique Ischemic Insult

Rahul S. Loungani, MD,a Sitharthan Sekar, MD,b Michael R. Rehorn, MD, MS,a Eric Black-Maier, MD,a Sreekanth Vemulapalli, MD,1 Sveti H. Shah, MD, MHS,a Robert W. Harrison, MDa

ABSTRACT

A 69-year-old man with a history of coronary artery ectasia, potentially resulting from an underlying heritable connective tissue disorder, presented with ventricular fibrillation. Despite medical management of ischemia, he developed recurrent ventricular tachycardia with poor neurological recovery. We highlight challenges in the management of coronary artery ectasia. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1662–6) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 69-year-old male with a history of non-ST-segment elevation myocardial infarction (NSTEMI) and coronary artery ectasia (CAE) presented following a cardiac arrest at home. The patient had reported indigestion shortly before he was discovered unresponsive by his spouse. She immediately initiated cardiopulmonary resuscitation and called emergency medical services, who arrived 20 min later and found the patient in ventricular fibrillation (VF). He was defibrillated, with return of spontaneous circulation, but he had 3 additional episodes of cardiac arrest en route to the hospital (polymorphic ventricular tachycardia [VT], pulseless electrical activity, and VF). On arrival to the intensive care unit, the patient was intubated and sedated, but he had intact pupillary reflexes. He was febrile (38.4°C), bradycardic, with a regular heart rhythm, and he had no murmurs. He had a normal jugular venous pressure with warm extremities and no peripheral edema, but he required norepinephrine to maintain adequate mean arterial pressure.

LEARNING OBJECTIVES

- To heighten awareness of various causes of coronary artery ectasia.
- To develop an approach to management of acute coronary syndromes in patients with coronary artery ectasia.
The patient first received a diagnosis of CAE in 2004 after he presented with NSTEMI at an outside institution. Coronary angiography at the time revealed aneurysmal, ectatic coronary vasculature, concerning for vasculitis or Kawasaki disease, and he was referred to our institution.

He informed us that his biological brother had also recently been given a diagnosis of CAE, and his father underwent surgery for abdominal aneurysms. The patient was subsequently evaluated for and received a diagnosis of thoracic aortic aneurysm and iliac artery aneurysms. He was transitioned to aspirin and warfarin and was referred to a geneticist.

Given his family history and the distribution of vascular involvement, vasculitis was believed to be an unlikely cause of his presentation, and limited genetic testing for mutations in matrix metalloproteinase proteins and tissue inhibitor of metalloproteinases-1 genes was ordered, but it did not identify a pathogenic variant. The patient was clinically stable on medical therapy consisting of aspirin and warfarin (international normalized ratio [INR] goal 2.0 to 3.0) for many years and had intermittent surveillance with coronary computed tomography angiography (Figure 1).

One year before cardiac arrest, he presented with NSTEMI. At the time of that admission, his INR was 1.8, cardiac troponin T (cTnT) level peaked at 1.38 ng/ml (upper reference limit 0.1 ng/ml), and the electrocardiogram was notable for sinus bradycardia, an early precordial R-wave transition, a premature ventricular contraction, and nonspecific T-wave changes (Figure 2A). He underwent coronary angiography (Figure 2B, Videos 1, 2, 3, and 4), which revealed diffuse CAE with Thrombolysis In Myocardial Infarction flow grade 1 to 2. An echocardiogram demonstrated a newly reduced left ventricular ejection fraction of 45% with regional hypocontractility in the inferior, posterior, and apical walls. Given the subtherapeutic INR on presentation, the risks and benefits of direct oral anticoagulant therapy were discussed with the patient, and he was transitioned to apixaban 5 mg twice daily. One month later, he again presented with NSTEMI. He was conservatively managed and transitioned back to warfarin with a higher INR goal (2.5 to 3.5). Genetic testing was revisited, and sequencing for a 48-gene panel assessing for heritable disorders of connective tissue was ordered (including genes for Marfan syndrome [MFS] and Loeys-Dietz syndrome).

In the context of known CAE and multiple previous NSTEMIs, the patient was presumed to have experienced an ischemic VT or VF arrest. However, coronary artery dissection or rupture, VT or VF related to underlying cardiomyopathy, electrolyte abnormalities, and sepsis were also considered.

The admission electrocardiogram (Figure 2B) was notable for sinus bradycardia with 0.5-mm ST-segment depressions in the anterior precordial leads, concerning, but not yet meeting criteria, for posterior ST-segment myocardial infarction. Admission laboratory studies included an INR of 1.6, lactate level of 4.7 mmol/l, and cTnT level of 0.88 ng/ml (upper reference limit 0.1 ng/ml). The echocardiogram (Video 5) revealed a left ventricular ejection fraction of 35% with inferior and posterior akinesis.

The results of genetic testing were reviewed and were notable for a missense mutation (heterozygous at c.164 G>A, p.Ser55Asn) in the transforming growth factor-beta (TGFβ3) gene, with conflicting clinical interpretations, including variant of uncertain significance, benign, and likely benign. In silico data were indeterminate with regard to effect on protein disruption.
MANAGEMENT

Given the absence of ST-segment elevation and the patient’s prolonged resuscitation and tenuous hemodynamic status, coronary angiography was deferred on arrival but was planned pending neurologic recovery (1). The patient was treated medically with dual antiplatelet therapy, unfractionated heparin, amiodarone, targeted temperature management, and ventilatory support. His cTnT level peaked at 8.12 ng/ml. He developed transient inferior-posterior ST-segment elevation (Figure 2C), but coronary angiography was deferred because of the perceived low likelihood of successful intervention in the setting of known complex anatomy and evolving evidence of poor neurologic recovery.

He subsequently developed VT storm (Figure 2D), which required lidocaine, repeat initiation of sedation, and ultimately stellate ganglion blockade, which only temporarily prevented recurrent VT. Given the patient’s poor neurologic prognosis, his family decided to withdraw care.

DISCUSSION

CAE, defined as diffuse segments of coronary artery at least 1.5 times that the size of the adjacent normal coronary vasculature, can be found in 1% to 5% of patients presenting for coronary angiography and is most commonly caused by atherosclerosis (2). Less common causes include vasculitis (Kawasaki, Takayasu), infections (mycotic, syphilitic), and genetic connective tissue disorders (MFS) (2).

Mechanisms of ischemia in CAE include: 1) flow alterations along aneurysm segments causing; 2) thrombus formation and/or embolization; 3) concomitant atherosclerosis; and 4) microvascular dysfunction (3,4). Optimal management of stable CAE centers on traditional atherosclerotic risk factor modification. Nitrates, however, have been shown to exacerbate myocardial ischemia and should generally be avoided as antianginal therapy (5).

Acute coronary syndromes in patients with CAE are difficult to manage and are associated with worse outcomes when compared with patients with normal
coronary anatomy (4). Percutaneous interventions are technically challenging, but they can include thrombectomy, intracoronary infusion of thrombolytic agents or glycoprotein IIb/IIIa inhibitors, or covered stenting in the appropriate clinical setting, although data are limited (4). Techniques for surgical repair include resection of aneurysmal segments or bypass grafting and are driven by individual patient anatomy (4). Medical management centers on antithrombotic therapy, with an observational analysis of 51 patients demonstrating that patients with CAE who were able to achieve significant (≥60%) time in therapeutic range with warfarin anticoagulation had significant reductions in adverse cardiovascular outcomes over 49-month follow-up (6). No data are currently available on the efficacy of direct oral anticoagulant therapy in this group.

With regard to etiology, the patient’s family history and aneurysmal dilations in other vascular beds triggered a genetic evaluation that revealed the patient was a carrier of a missense variant in the TGFβ3 gene. Variants in TGFβ3 have been associated with aortic aneurysmal disease with clinical overlap with MFS and Loeys-Dietz syndrome (7), but there remain conflicting interpretations of our patient’s variant because of limited available data.
FOLLOW-UP

Autopsy revealed the following: 1) coronary vasculature with intimal fibrosis, replacement scar, but no evidence of necrosis or healed arteritis; 2) a subacute, large transmural infarct from the posterior septum to the lateral free wall, with evidence of thrombus in the proximal left circumflex artery; and 3) acute thrombus in the distal left main artery. To investigate further whether the identified variant of uncertain significance is pathogenic, we are in the process of contacting family members for genetic evaluation.

CONCLUSIONS

We present a case of ischemic cardiac arrest in the context of diffuse CAE, potentially resulting from an underlying genetic connective tissue disorder, and highlight challenges in the management of these patients.

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KEY WORDS cardiac arrest, connective tissue disease, coronary ectasias, coronary thrombosis

APPENDIX For supplemental videos, please see the online version of this paper.
Multimodal Imaging of Post-Stenting Mycotic Coronary Pseudoaneurysm Complicated by Device Fracture and Myocardial Abscess

Gloria Santangelo, MD,a,* Andrea Buono, MD,b,* Antonio Silvestro, MD,b Manuela Giglio, MD,c Maurizio Tespili, MD,b Alfonso Ielasi, MDb

ABSTRACT

Mycotic coronary aneurysm and pseudoaneurysm are rare infective complications of percutaneous coronary interventions, associated with poor prognosis. Multimodality imaging is recommended to achieve a correct diagnosis. We present a case of post-stenting mycotic coronary pseudoaneurysm complicated by myocardial abscess in which we used different imaging tools, each carrying additional information. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1667–70) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 70-year-old man was admitted to our unit for an episode of typical chest pain, which increased at rest. At our assessment there were no constitutional symptoms and hemodynamic parameters were normal. Electrocardiogram (ECG) did not show significant alterations, but cardiac enzymes were elevated (troponin I 5,060 ng/ml, normal value <0.045; creatine kinase-myocardial band 9.30 ng/ml, normal range 1 to 3.6). A trans thoracic echocardiogram (TTE) showed mild pericardial effusion with mild impairment of left ventricular ejection fraction (50%) due to anterior wall hypokinesia. In suspicion of acute coronary syndrome, the patient underwent coronary angiography that revealed a critical calcified stenosis of the mid left anterior descending artery (LAD), treated using percutaneous coronary intervention (PCI) and implantation of 3 overlapping drug-eluting stents (DES) (Figures 1A to 1B). In detail, the procedure was carried out with successful pre-dilatation of the proximal-mid LAD segment (total diseased segment’s length 35 mm, with 3.0 mm and 2.5 mm proximal and distal reference vessel diameters, respectively), with fully expanded 2.0 mm and 2.5 mm noncompliant balloons. A 2.5 × 15 mm DES (Resolute Onyx, Medtronic, Milan, Italy) was deployed in the proximal-mid LAD. Coronary angiography (CAG) showed normal flow through stents and complete revascularization. Anticoagulation therapy was maintained 6 days after PCI, then oral aspirin and clopidogrel were prescribed. Troponin levels were restored within 1 week. On day 7, a TTE showed mild pericardial effusion, with moderate impairment of left ventricular ejection fraction (45%). On day 14, a CT scan of the chest revealed hypodense areas suggestive of myocardial abscess. On day 21, the patient underwent repeat angiography with new CAG showing 1.8 mm residual stenosis in the distal LAD. Discharge was on day 28 on oral aspirin and clopidogrel.

LEARNING OBJECTIVES

- Multimodality imaging is recommended to achieve a diagnosis of post-stenting mycotic coronary pseudoaneurysm.
- The mortality rate of post-stenting mycotic coronary pseudoaneurysm is high despite combined medical and surgical therapy.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors’ institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the JACC: Case Reports author instructions page.

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artery intervention echocardiogram TTE = trans-thoracic = percutaneous-coronary-PCI LAD = left anterior descending = electrocardiogram ECG = drug-eluting stents DES = coronary = cardiac magnetic CMR AND ABBREVIATIONS ACRONYMS

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September 2020:1667-1668

Mycotic Coronary Pseudoaneurysm Complicating PCI

Figuress 2A to 2C, Video 1). Blood cultures resulted positive for Staphylococcus aureus.

MINNEAPOLIS, MINNESOTA) was distally implanted followed by a 2.75 × 22 mm Resolute Onyx delivered in overlap in the proximal segment. Due to the suboptimal angiographic result (plaque shift), a third 2.5 × 12 mm Resolute Onyx was distally implanted in overlap. Proximal and distal post-dilatations were performed with a 3.0-mm and a 2.75-mm noncompliant balloon, respectively. Final Thrombolysis In Myocardial Infarction flow grade 3 was achieved, without evidence of coronary dissection. The day after, the patient presented with fever (temperature 38.5°C) and cough and 48 h after PCI he developed episodes of shortness of breath and atypical chest pain. C-reactive protein (27.1 mg/dl, normal value <0.3 mg/dl) as well troponin I (7,320 ng/ml) values were high. Empirical β-lactam antibiotic treatment was started.

PAST MEDICAL HISTORY

History included hypertension, type 2 diabetes mellitus, dyslipidemia, cocaine misuse, chronic idiopathic anemia, and thrombocytopenia (60 × 10³/µl, normal range, 130 to 400 × 10³/µl).

DIFFERENTIAL DIAGNOSIS

The differential diagnosis was acute myo-pericarditis, pneumonia, and pleurisy.

INVESTIGATIONS

Diffuse ST-segment elevation (pericarditis-like) was detected at ECG, which was performed 72 h after PCI. Pericardial effusion enlargement with further left ventricular ejection fraction reduction (45%), in the absence of active valve endocarditis, were documented at a new TTE assessment. To exclude myo-pericarditis, 96 h after PCI, a cardiac magnetic resonance (CMR) was performed: severe non-tamponade circumferential pericardial effusion was confirmed with the surprising evidence of a coronary pseudoaneurysm (cPSA) at the level of a previously treated mid-LAD segment, with a possible stent discontinuity (Figures 2A to 2C, Video 1). Blood cultures resulted positive for Staphylococcus aureus.

MANAGEMENT

Intravenous antiobiogram-guided therapy with oxacillin was started. On the basis of clinical, laboratory, and imaging findings, a diagnosis of post-stenting myotic (infected) cPSA was formulated. Our multidisciplinary heart team judged the patient at very high surgical risk and a percutaneous treatment strategy was chosen to prevent the risk of PSA expansion, resulting in rupture and cardiac tamponade. The following coronary angiography confirmed the large mid-LAD PSA, showing fracture of overlapping implanted DES (Figure 1C, Video 2). PCI with a 3.0 × 18 mm covered stent (BeGraft; Bentley, Hechingen, Germany) implantation (inflated at maximum 12 atm) was performed. However, for the persistence of pseudoaneurysm filling, the other 2 3.0 × 18 mm BeGraft covered stents were placed proximally and distally with a large overlap area with the previous one (maximum inflation pressures 12 atm), documenting full exclusion of PSA, without evidence of leaks (Figure 1D). The PSA infective nature was confirmed using PET, which also documented an increased radiotracer uptake of the mid–left ventricular anterolateral wall at the stented segment level, compatible with a myocardial abscess (Figure 3A). TTE also detected an irregular and hypoechoic area within the left ventricular myocardium (Figure 3B). A multi-slice computed tomography scan was planned to assess the feasibility of abscess surgical drainage. However, a multi-slice computed tomography scan confirmed the cPSA exclusion associated with an extended inflammatory mass deeply located within the myocardium, making a surgical excision not feasible (Figure 3C). Conservative antibiotic treatment was administered, but, despite an initial promising response, the patient died 3 months later due to sepsis.

DISCUSSION

Mycotic coronary aneurysm and pseudoaneurysm are a rare infective disease of the arterial vessel walls. The development could be linked to the presence of an infective endocarditis or could represent a primary infection at the site of an implanted coronary stent (1). Bacteria, particularly S aureus, are the most common etiological agents (2). Although mycotic coronary aneurysm onset is usually subacute, time to presentation can be extremely variable, with several cases (as in our patient) reported to occur even in the early days after PCI (3). Diagnosis is challenging because symptoms can be subtle and there is not a “one-stop-shop” imaging test able to provide complete information to reach the diagnosis (4). Morbidity and mortality are high, especially in the context of pseudoaneurysm,
which carries an increased risk of rupture, or in the case of infectious dissemination, involving the myocardium and pericardium. Prompt treatment is required, although, to date, little evidence concerning the optimal strategy is available and the mortality rate remains high independent from the combined efforts of medical and surgical therapy (2). In the presented case, surgical correction was excluded due to the prohibitive pre-operative mortality risk. For this reason, we decided to treat the patient percutaneously at least to minimize the risk of cPSA rupture (a well-known fatal consequence). Antibiotic treatment was administered to control infections. However, we observed a dismal prognosis, which culminated with the patient’s death.

CONCLUSIONS

In patients with suspicious of mycotic coronary aneurysm or pseudoaneurysm presenting with a recent history of PCI associated with clinical and laboratory findings of current infection, a multimodality imaging strategy (comprehensive of invasive and noninvasive tools) is strongly recommended and plays a pivotal role in confirming the diagnosis.

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KEY WORDS mycotic coronary aneurysm, myocardial abscess, staphylococcal infections, stent fracture

APPENDIX For supplemental videos, please see the online version of this paper.
Navigation of a Dormant AV Fistula for PCI in a Patient With High-Risk NSTEMI

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ABSTRACT

Arteriovenous (AV) fistulae for hemodialysis in patients with end-stage renal disease usually prevent ipsilateral transradial access (TRA) for coronary angiography. We present a case of coronary angiography and percutaneous coronary intervention via left TRA with navigation through a dormant AV fistula in a patient with limited vascular access. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1671–4) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 61-year-old male patient presented to the emergency department with acute dyspnea and productive cough. He was initially admitted to the hospital ward and treated presumptively for health care-associated pneumonia based on chest x-ray opacities and an elevated procalcitonin level. On hospital day 1 he had an acute change in status with a decrease in his blood pressure to 80s/40s mm Hg.

PAST MEDICAL HISTORY

Past medical history included end-stage renal disease (ESRD) on hemodialysis, peripheral artery disease (PAD) with prior right above-the-knee and left below-the-knee amputations, and type 2 diabetes mellitus. The patient had previously undergone creation of an AV fistula in the left forearm. Unfortunately, this fistula failed and the patient required placement of a tunneled right internal jugular vein hemodialysis catheter.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis included severe sepsis due to pneumonia, acute coronary syndrome complicated by cardiogenic shock, and acute pulmonary embolism.

INVESTIGATIONS

An electrocardiogram was obtained that showed new lateral T-wave inversions and his cardiac biomarkers were elevated, diagnostic for a non-ST-segment
elevation myocardial infarction (NSTEMI). He was admitted to the cardiac intensive care unit (CICU) and required norepinephrine to maintain a mean arterial pressure >65 mm Hg. A right radial arterial line was placed for monitoring. Transthoracic echocardiography showed an ejection fraction of 40% (previously normal) with anterior, septal, and apical wall motion abnormalities.

On examination, the patient’s bilateral femoral arterial pulses were absent. The right radial site was used for an arterial line. He had a normal left radial and bounding left brachial pulse. Review of prior computed tomography angiography showed high-grade stenoses of the bilateral common iliac arteries that were felt to be likely to prevent crossing with a wire or catheter. Given concern regarding the feasibility of femoral access due to severe PAD and the need for continued hemodynamic monitoring via the right radial artery, the decision was made to pursue coronary angiography via left radial arterial access through the dormant AV fistula.

**MANAGEMENT**

The left radial artery was accessed using the counterpuncture approach. A 6-F Glidesheath slender (Terumo Interventional Systems, Somerset, New Jersey) could not be fully advanced into the radial artery due to extensive calcification but was able to be seated well enough to provide adequate wire and catheter support. A 5-F JR 4 diagnostic catheter was introduced over a Baby-J guidewire into the forearm and advanced to the level of the fistula. Significant tortuosity in the AV fistula prevented further advancement. A radial arteriogram demonstrated occlusion of the distal brachial artery with a patulous vein segment connecting the proximal radial artery with the brachial artery (Figure 1). After unsuccessful attempts to navigate this segment with a 0.035-inch Wholey wire and an angled 0.035-inch Glidewire, the venous segment was crossed with a 0.014-inch Runthrough coronary wire (Terumo Interventional Systems) (Figure 2), and the diagnostic catheters were advanced through the dormant fistula to the level of the coronary sinus. Coronary angiography demonstrated a heavily calcified 99% lesion in the left anterior descending (LAD) and first diagonal coronary arteries and the decision was made to perform PCI (Figure 3A).

Exchange for a 6-F EBU 4 guide catheter (Medtronic, Minneapolis, Minnesota) over an exchange-length 0.035-inch J wire failed due to redundancies in the venous segment of the AV fistula preventing catheter advancement. The 0.035-inch guidewire was exchanged for the 0.014-inch coronary wire; advancement of the guide catheter using the balloon-assisted tracking (BAT) technique (1) with

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**ABBREVIATIONS AND ACRONYMS**

AV = arteriovenous  
BAT = balloon-assisted tracking  
CICU = cardiac intensive care unit  
ESRD = end-stage renal disease  
LAD = left anterior descending coronary artery  
NSTEMI = non-ST-segment elevation myocardial infarction  
PAD = peripheral artery disease  
PCI = percutaneous coronary intervention  
TRA = transradial access

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**FIGURE 1** Radial Arteriogram of Arteriovenous Fistula

Radial arteriogram showing the arteriovenous fistula with venous connection (black arrow) between the proximal radial (white arrow, with catheter in situ) and proximal brachial (striped arrow) arteries. The distal brachial artery is occluded.

**FIGURE 2** Navigation of the Arteriovenous Fistula Using a Coronary Wire

Radial arteriogram showing the arteriovenous fistula with venous connection (black arrow) between the proximal radial (white arrow, with catheter in situ) and proximal brachial (striped arrow) arteries. The distal brachial artery is occluded.

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**FIGURE 3A** Navigation of the Arteriovenous Fistula Using a Coronary Wire

Exchange for a 6-F EBU 4 guide catheter (Medtronic, Minneapolis, Minnesota) over an exchange-length 0.035-inch J wire failed due to redundancies in the venous segment of the AV fistula preventing catheter advancement. The 0.035-inch guidewire was exchanged for the 0.014-inch coronary wire; advancement of the guide catheter using the balloon-assisted tracking (BAT) technique (1) with
a 2.0 × 20-mm Euphora balloon (Medtronic) was attempted but initially failed due to inability to cross the fistula due to guidewire kinking within the venous segment. Attempts to advance the guide catheter over a 0.038-inch Amplatz Super Stiff guidewire (Boston Scientific, Marlborough, Massachusetts) also failed. The guide catheter was downsized to a 5-F EBU 4 (Medtronic); again using BAT, which was able to pass with some difficulty through the AV fistula (Figure 4).

PCI was then successfully performed for the LAD lesion using predilatation with sequential 1.0 × 15-mm, 2.0 × 15-mm, and 2.5 × 15-mm Sapphire balloons (Cardiovascular Systems, St. Paul, MN) and then a 3.0 × 12-mm Resolute Onyx drug-eluting stent (Medtronic), which was postdilated using a 3.0 × 12-mm Sapphire balloon. PCI of the diagonal lesion was accomplished using 1.0 × 15-mm Sapphire and 2.0 × 20-mm Euphora balloons and then a 2.25 × 22-mm Resolute Onyx stent (Figure 3B).

**DISCUSSION**

We have described a complex case of diagnostic coronary angiography and PCI via a left radial artery approach requiring navigation through a dormant dialysis AV fistula in a NSTEMI patient with limited arterial access options. Significant tortuosity and redundancy were encountered that posed challenges to the standard techniques for catheter advancement. In this case, the combination of 2 techniques—downsizing of the guide catheter to a 5-French system and BAT—was critical for successful navigation of the AV fistula and ultimately, PCI.

Transradial access (TRA) for coronary angiography and PCI has become the preferred approach for many operators worldwide. TRA is considered the standard of care in the management of acute coronary syndromes in Europe (2) and a recent scientific statement published by the American Heart Association
recommends the adoption of a “radial first” approach for PCI in the United States, based on evidence that this approach is associated with lower rates of bleeding and vascular complications compared with transfemoral access (3).

While the prevalence of ESRD has been stable since approximately 2,000 in the United States (4), there has been a trend toward increased use of the upper arm (rather than lower arm) as the location for AV fistula creation. This has raised concerns that patients, especially younger ones, may exhaust all available potential vascular access sites for hemodialysis access (5). Several studies have examined the reluctance of PCI operators to choose TRA in patients with ESRD due to concerns about radial artery occlusion (6,7). Meanwhile, patients with chronic kidney disease are at increased for coronary artery disease, PAD, and bleeding, with a predicted mortality rate of approximately 40% at 2 years for patients with ESRD after acute myocardial infarction (8). Clearly, vascular access can be very challenging in this patient population and radial access has the potential to significantly reduce bleeding and potentially mortality, especially in the setting of acute coronary syndromes (9). In the case presented, the patient’s right arm was being used for an arterial line in the setting of cardiogenic shock and both legs had severe PAD with absent pulses; however, similar access challenges may occur in a patient in whom both arms had been used for repeated AV fistula creation.

TRA has been demonstrated as a safe approach for catheter-based repair of AV fistulae, including radiocephalic anastomoses in the lower arm (10). Our case demonstrates that in selected cases, navigation through a dormant AV fistula may be considered in clinical situations in which the usual arterial access options are unavailable. Although it was not necessary in our case, access via the ipsilateral distal radial artery (“snuffbox”) or ulnar artery could also be considered to limit the risk of proximal radial artery occlusion in patients with AV fistulae. It should be noted that our report should not be interpreted as advocating for coronary angiography through an active AV fistula.

**FOLLOW-UP**

After PCI, the patient was transferred back to the CICU, where his hemodynamics improved and he was rapidly weaned off vasopressors. He was discharged home on post-procedure day 14 and was doing well from a cardiac standpoint at 1 year of follow-up.

**CONCLUSIONS**

With use of upper-extremity AV fistulae as the first-choice option for dialysis access in patients with ESRD, radial access for coronary angiography may be limited in such patients. However, in absence of other vascular access options, navigation through a dormant AV fistula might be considered.

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**KEY WORDS** coronary angiography, percutaneous coronary intervention, peripheral vascular disease.
A 66-year-old man with a ramus chronic total occlusion had escalating angina and a high-risk stress test. Coronary angiography the day of his planned ramus chronic total occlusion percutaneous coronary intervention demonstrated a large left main aneurysm. He underwent bypass with left internal mammary artery left anterior descending and failed saphenous vein graft ramus, followed by successful covered stent placement from left main into left circumflex and ramus chronic total occlusion percutaneous coronary intervention. (Level of Difficulty: Advanced.)

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of 7.5%), and previously treated throat cancer for which he received radiation and chemotherapy.

**DIFFERENTIAL DIAGNOSIS**

The pathogenesis of coronary artery aneurysm (CAA) is poorly understood. Because trauma is believed to be a provoking factor, we hypothesized that his recent prior PCIs in combination with his various coronary artery disease risk factors may have contributed to the development of his newly discovered LM CAA.

**INVESTIGATIONS**

On discovery of the patient’s large LM CAA, intravascular ultrasound (Philips Healthcare, Amsterdam, Netherlands) of the LM was performed. It revealed a maximal aneurysmal dimension of at least 10 × 10 mm beginning approximately 2 mm from the aortic wall. Decision was made for the patient to undergo a cardiac computed tomography scan. This computed tomography confirmed a saccular aneurysm measuring 13 × 13 mm (Figure 1).

**MANAGEMENT**

The patient was placed on anticoagulation with warfarin, with goal international normalized ratio of 2 to 3. The case was discussed in detail with our cardiothoracic surgery colleagues. The decision was made for him to undergo coronary artery bypass surgery with the plan for him to receive a left internal mammary artery (LIMA) to his left anterior descending (LAD) artery and vein grafts to his ramus and LCx. A percutaneous strategy would only be instituted if the bypass grafts were unsuccessful. Ultimately, he received a LIMA to LAD and a single saphenous vein graft was presumably anastomosed to his ramus.

Post-bypass, the patient continued to experience his rest angina. He remained afebrile, with a heart rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We elected to repeat his angiography 3 days after his surgery to evaluate his graft patency and rate of 65 beats/min and a blood pressure of 130/80 mm Hg. We electe...
Takayasu arteritis, Behçet disease, syphilis), connective tissue disorders (systemic lupus erythematosus, rheumatoid arthritis, ankylosing spondylitis, progressive systemic sclerosis), and hereditary collagen defects (Marfan syndrome, Ehler-Danlos syndrome) (1,3).

In light of an era of efficient coronary angiography, an LM aneurysm remains rare. In a study conducted by Topaz et al. (4), there was an incidence for LM aneurysms of 0.1% among 20,332 adult patients who underwent routine coronary angiography. It is because of the paucity of these cases in literature, that treatment options are unclear. However, most would agree that the principal concern when dealing with aneurysms is the development of thrombus and subsequent embolization. Rath et al. (5) published a case series of 5 patients with coronary aneurysms who were asymptomatic without other critical lesions who went on to suffer from acute myocardial infarctions secondary to complete occlusion of their aneurysmal vessels.

There are currently no guidelines for the management of CAA. Therefore, because our patient had an LM CAA and was unable to receive 3 grafts, we elected to proceed with this novel hybrid approach. Our initial plan was to seal the CAA with the covered stent extending from LM into the LCx because this vessel was unable to be grafted. Unfortunately, in discovering that his saphenous vein graft to ramus was not patent, we had to change our strategy. We were able to extrapolate the idea of fenestrating through a covered stent, to allow flow into another territory from other case reports (6).

Before his PCI, we did discuss the need for left ventricular support. However, because our patient had a patent LIMA to his LAD with an ejection fraction of 45%, we did not believe it was necessary to place support upfront. Fortunately, throughout the intervention, he remained hemodynamically stable.

**FOLLOW-UP**

Post-PCI, the patient had TIMI flow grade III into his LAD, ramus, and LCx with complete relief of his angina. He was discharged 2 days later and is currently underway with cardiac rehabilitation.

**CONCLUSIONS**

CAAs can result from a variety of factors and our patient likely developed his from trauma induced during prior coronary interventions. Treatment options typically involve anticoagulation to prevent complication from thrombus burden and surgical intervention. However, if the LM is involved, a hybrid approach may be a viable option especially if all vessels are unable to receive a bypass graft.

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KEY WORDS computed tomography, coronary artery aneurysm, coronary artery bypass, high-risk, hybrid, percutaneous coronary intervention, stents

APPENDIX For supplemental videos, please see the online version of this paper.
Intracoronary Lithoplasty in Percutaneous Treatment of Challenging Calcified Coronary Lesions

Alfredo Marchese, MD, PhD,a,b Antonio Tito, MD,b Fabrizio Resta, MD,b Antonio Colombo, MDa,b

ABSTRACT

Unexpanded stents in calcified coronary stenosis is a problem where intravascular lithotripsy could be effectively employed. In these 2 cases, we report possible issues associated with the use of this technology. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1679-83) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Un-dilatable and severely calcified lesions are independent predictors of in-hospital and late major adverse cardiac events. Despite the availability of dedicated devices, stents implanted in calcified lesions do not always achieve an optimal expansion. Use of rotational atherectomy, high-pressure noncompliant balloons, cutting balloons, and scoring balloons are the most widely used tools to appropriately prepare severely calcified plaques. Nevertheless, the use of these devices is occasionally associated with complications, and an optimal result is not always guaranteed.

Complications associated with the need for aggressive lesion preparation are no-reflow, vessel rupture, and extensive dissection. The recent introduction of the coronary intravascular lithotripsy (IVL) system (Shockwave Medical, Fremont, Califórnia) seems to effectively correct stent under-deployment. Some concerns exist regarding the bulky profile of the device and its cross-ability when a high degree of stent under-expansion is present (1).

A second challenging subset is the need to deliver IVL in multivessel calcified stenosis simultaneously. Current experience with the IVL system has proven to be safe. However, some recent reports have warned about the evidence of coronary vasoconstriction (2) and electrophysiological side effects (3). This paper describes the feasibility of IVL in 2 clinical cases highlighting potential issues that could arise.

LEARNING OBJECTIVES

- Undilatable lesions are particularly challenging and expose the patient to high risk of under-expanded stents, especially under bail-out conditions.
- When dealing with an acute or chronically under-expanded stent, IVL may become the standard of care if high-pressure balloons fail.
- Recognizing the likelihood that IVL could induce a vasoconstriction immediately after or during procedures.

From the aGVM (Gruppo Villa Maria) Care and Research, Maria Cecilia Hospital, Cotignola, Italy; and the bGVM (Gruppo Villa Maria) Care and Research, Ospedale Santa Maria, Bari, Italy. The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors’ institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the JACC: Case Reports author instructions page.

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DEALING WITH ACUTE STENT UNDER-EXPANSION. A 67-year-old man, hypertensive and diabetic, with angina on effort, had a chronic total occlusion of the proximal left anterior descending artery (LAD) with a heavily calcified mid-segment and a proximal blunt stump (Figures 1A and 1B).

The setup was the left radial access for collateral opacification and the right femoral access for the target lesion. The parallel wire technique, supported

#### FIGURE 1 Bail-Out Handling of Stent Under-Expansion

(A) Left anterior descending artery chronic total occlusion with ambiguous cap. (B) Right-to-left collateral filling. (C) Extensive coronary dissection. (D) “Dog-boning” effect at the narrowest under-expanded stents and contrast-dye staining. (E) Stent boost shows circumferential calcification with severe stent under-expansion. (F, G) Minimal luminal diameter at the narrowest steel obstruction. (H) Intravascular lithotripsy balloon inflation showing full stent expansion.
by a FineCross (Terumo, Tokyo, Japan) microcatheter and wire escalation to a Pilot 200 (Abbott Laboratories, Chicago, Illinois) crossed successfully. The lesion was prepared with 2.0/20-mm low-profile balloon and high-pressure noncompliant (NC) balloons of 3.0/15 mm, followed by a 3.25/15-mm balloon up to 25 atm to achieve a 1:1 balloon/artery ratio without optimal balloon expansion. These aggressive dilation maneuvers caused a dissection with a large flap and contrast dye in the false lumen extending backwards up to the ostium of the LAD (Figure 1C).

The patient complained of chest pain associated with hemodynamic instability and marked ST-segment depression. Two overlapped stents were urgently implanted. Despite resolution of the coronary occlusion, the patient still complained of chest pain. One of the stents appeared to be underexpanded despite post-dilation with a NC balloon 3.5/15 mm up to 28 atm (Figure 1D).

Stent boost magnification (Philips Medical System, Best, the Netherlands) confirmed severely underexpanded and distorted stent struts distal to the overlapped segment (Figure 1E). Despite the fact that coronary flow was recovered, the hemodynamic status got slightly better with persisting chest pain and a faint collateral perfusion.

A 3.5-mm Shockwave lithoplasty balloon (Shockwave Medical Inc., Fremont, California) crossed the narrowest under-expanded segment, and a rescue treatment was immediately delivered. The Shockwave balloon inflation fully expanded after 2 cycles of 10 impulses inflated up to 4 and then further to 6 atm (Figures 1F and 1G). Stent Boost after IVL showed a well-expanded stent without any distortions (Figure 1H). Final optimization with an NC balloon 3.5/15 mm at 16 atm was performed with an immediate recovery of the patient’s clinical status.

**DIFFUSE ST-SEGMENT ELEVATION AFTER IVL AT MULTIVESSEL SEVERE CALCIFIED LESIONS.** A 73-year-old man, presented with effort angina and multiple reversible perfusion defects. Angiography showed a long calcified Medina 1.0.1 bifurcation lesion involving the proximal LAD and the first diagonal branch (D1). Moreover, multiple tandem stenoses on a severely bent and calcified right coronary artery were present (Figures 2A and 2B).

The LAD stenosis was dilated using a 3.0/20-mm NC balloon up to 12 atm, but incomplete balloon expansion occurred. The balloon waist resolved after 2 cycles of 10 impulses with a 3.0/12-mm balloon inflated to 6 atm of IVL delivery (Figure 2C). A T-and-protrusion stenting technique was then performed to treat the bifurcation lesion (Figure 2D).

The right coronary artery issue was undertaken by the femoral access using an AL1 guiding catheter and multiple buddy wires. After pre-dilation with a standard 2.5/20-mm balloon, the IVL was easily advanced, and the complete balloon expansion (3.5/12 mm
inflated to 6 atm) was achieved after 3 cycles of 10 impulses (Figures 2E to 2G). Multiple overlapped stents were implanted followed by high-pressure NC balloon dilation (Figure 2H).

An optimal result was obtained with a thrombolysis in myocardial infarction flow grade III. However, in the recovery room, the patient complained of chest discomfort associated with diffuse ST-segment elevation in multiple leads without reciprocal ST-segment changes (Figures 3B and 3C).

Urgent angiography showed the treated vessels were fully open with good distal flow without any side branches occlusion. There was new milking appearance in the mid-LAD mimicking myocardial bridging (Figures 4A to 4C). Intracoronary nitroglycerin was avoided in order to not worsen the bridging, and the complete resolution of the ST-segment elevation was obtained after 40 min, during which verapamil was intravenously infused (10 mg/h) (Figure 3D). The patient completed an uneventful hospital stay without new pathological Q waves (Figure 3E) but with a negligible rise of troponin-I.

**DISCUSSION**

These cases illustrate both the feasibility and the drawbacks of using IVL in 2 complex scenarios, such as the bail-out treatment of unexpanded stents and the effects of erogations delivered on multivessel severely calcified lesions.

Regarding the former case, several reports illustrated the safety and the efficacy of IVL used in stable, chronically under-expanded stents. A recent report discussed the feasibility of IVL compared with general NC or new generation cutting balloons and highlighted the concern about the relatively bulky profile of lithotripsy balloons (1).

In the first case, the IVL balloon easily crossed the under-expanded segment because no angulation or tortuosity was encountered, and the minimal luminal diameter at the narrowest steel obstruction resulted in larger minimal luminal diameter (MLD) of 1.20 mm than the reported crossing profile of 1.12 mm of the 3.5-mm IVL balloon (Figures 1F and 1G).

In the second case, the occurrence of ST-segment elevation following multiple IVL deliveries is an unexpected finding, and the following final considerations may arise:

- Even if there are no compelling data to support the fact that vasoconstriction is more likely to occur in multivessel IVL delivery compared to the single-vessel delivery, it is worth mentioning that only 1 lesion per patient was treated in previous studies (4).
The prompt resolution of both the myocardial bridging and of the diffuse ST-segment elevation by the administration of verapamil strengthens the hypothesis of vasoconstriction.

Alternatively, the diffuse electrocardiography changes that occurred could be attributed to the capacity of coronary IVL to trigger ventricular ectopies and cellular depolarization in response to a mechanoelectrical coupling between the energy generated by the sonic pressure of the IVL and the local stretch-activated cellular ionic channels, as previous studies have reported (3).

**CONCLUSIONS**

The adoption of IVL as a bail-out procedure for underexpanded stents seems to be a promising option. When multivessel calcified target lesions are undertaken in the same setting, some potential new drawbacks could be encountered.

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**KEY WORDS** coronary angiography, myocardial ischemia, percutaneous coronary intervention
MINI-FOCUS ISSUE: CORONARIES

CASE REPORT: CLINICAL CASE

A Novel Case of Spontaneous Coronary Artery Dissection During Cabergoline Therapy for Prolactinoma

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ABSTRACT

We present a case of spontaneous coronary artery dissection associated with cabergoline treatment for prolactinoma. A 31-year-old woman with history of hypertension and prolactinoma, treated with cabergoline, presented with chest pain. She had non-ST-segment elevation myocardial infarction with double vessel coronary artery dissection and was treated with coronary artery bypass grafting. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1684–7)

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HISTORY OF PRESENTATION

A 31-year-old woman presented with complaint of chest pain. She denied tobacco, drug, or alcohol use, and she reported there was no known family history of genetic disease, cardiac disease, or sudden death. On initial evaluation, vital signs demonstrated a heart rate of 62 beats/min and a blood pressure of 110 mm Hg. Physical examination was significant for an anxious female with physical distress caused by intermittent chest pain but no focal abnormal findings were identified. An electrocardiogram showed diffuse T-wave inversions in II, III, aVf, and V1 to V6. Laboratory tests showed an initial troponin I of 0.06 ng/ml (normal range, <0.40 ng/ml) but reflected a normal complete blood count and basic metabolic panel. Patient was given aspirin (325 mg) and clopidogrel (600 mg) at the outside hospital she initially presented to. On presentation to our facility, her troponin I level increased to 2.8 ng/ml.

LEARNING OBJECTIVES

- SCAD commonly occurs in young females without risk factors of atherosclerotic CAD.
- The use of cabergoline to treat hyperprolactinemia could be related to its incidence.
- CABG was effective in the case of a symptomatic patient with ongoing ischemia despite medical therapy. PCI could be associated with an increased risk of iatrogenic dissections or extensions of dissection.

PAST MEDICAL HISTORY

The patient had a previous medical history of hypertension treated with amlodipine (10 mg/day). She delivered 1 child 11 years ago. The patient had reported symptoms characteristic of amenorrhea, galactorrhea, and infertility 2 years ago. Her prolactin level was elevated to 160 ng/ml (normal range, 2.8 to...
29.2 ng/ml) but she was not treated for prolactinoma for 1 year because of noncompliance with medical recommendations. A magnetic resonance imaging detected a 2.3-cm pituitary mass and a prolactin level of 236 ng/ml 7 months ago. She was started on cabergoline (0.25 mg twice weekly) for prolactinoma. After completing 3 months of therapy, she stopped refilling her prescription. Three weeks later (3 months before this presentation), she visited the emergency department with complaint of chest pain. She was discharged home because electrocardiogram did not show significant ST-segment changes and echocardiogram revealed normal ejection fraction. Her endocrinologist restarted her back on cabergoline at her previous dose.

**DIFFERENTIAL DIAGNOSIS**

Based on the initial presentation, electrocardiogram findings, and elevated troponin, differential diagnosis included non-ST-segment elevation myocardial infarction, myocarditis, and stress cardiomyopathy.

**INVESTIGATION**

A coronary angiogram revealed normal left main, diffuse 99% stenosis of the proximal to mid left anterior descending artery, 90% stenosis at the first diagonal branch, normal left circumflex, and total occlusion of the mid right coronary artery (RCA) without visible collaterals (Figure 1, Video 1). RCA was likely an acute flow-limiting dissection and the culprit lesion. An echocardiography showed 60% of ejection fraction with hypokinesis of inferior and septal wall. A lipid panel test was not significant (cholesterol, 164 mg/dl; low-density lipoprotein, 123 mg/dl; high-density lipoprotein, 52 mg/dl; and triglyceride, 53 mg/dl).

**MANAGEMENT**

Considering the patient’s young age and staccato chest pain, which was related to high blood pressure, coronary artery dissection was suspected. Percutaneous coronary intervention (PCI) was not performed. Blood pressure control resolved chest pain. An intra-aortic balloon pump was placed and the patient was treated with intravenous heparin and nitroglycerine infusions in anticipation of coronary artery bypass grafting (CABG) for definitive treatment. Ten hours later, the patient had a recurrence of chest pain with increasing troponin I of 6.5 ng/ml and was taken for on-pump CABG. The left internal thoracic artery was anastomosed to left anterior descending artery and the right internal thoracic artery to RCA. Radial artery was anastomosed to the diagonal artery. Tissue along the diagonal artery and left anterior descending artery was inflamed and swollen (Figure 2). Once arteries were opened, they were found to have evidence of dissection with false lumen, chronic thrombosis, and a dissection flap. The RCA was similarly dissected. The chest was left open because of profound hypotension during an attempt to close.

**DISCUSSION**

Spontaneous coronary artery dissection (SCAD) is an uncommon cause of acute coronary syndrome or sudden cardiac death (1). It is identified in 0.2% to

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**FIGURE 1** Pre-Operative Coronary Angiogram

(A) In the right anterior oblique caudal view, left main and the left circumflex was normal. (B) In the left anterior oblique cranial view, the proximal to mid left anterior descending artery showed diffuse 99% stenosis. There was a 90% stenosis at the bifurcation of the first diagonal branch. (C) In the left anterior oblique cranial view, the mid right coronary artery was 100% occluded.
1.1% of coronary angiographies performed for acute coronary artery syndrome (2). SCAD predominately affects young females with some experiencing the condition in a life-threatening manner than others. Although it is a rare disease, it can be underdiagnosed because of the perception that coronary artery disease (CAD) does not affect young patients. In our case, the patient presented to the emergency department with chest pain 3 months before undergoing CABG. She may have had a SCAD event at that time, from which she recovered, followed by another event that led to the second presentation. It is clear that CAD may not likely be considered when young patients complain of chest pain. Intramural hematoma within the wall of a coronary artery is characteristic after SCAD. This is caused by intimal tear or a spontaneous hematoma arising from the vasa vasorum within the vessel wall (3). The cause of SCAD could be multifactorial, including underlying arteriopathies, genetic factors, hormonal influences, or systemic inflammatory diseases. Among arteriopathies, the association of SCAD with fibromuscular dysplasia has been reported. Fibromuscular dysplasia affects any arteries and can manifest as arterial stenosis, aneurysm, or dissection (4). There is only 1 previous case report about SCAD during use of cabergoline (5). Cabergoline is an ergot derivative, which can cause vasospasm leading to dissection of arteries (6). There may be a relationship between cabergoline and SCAD. Besides this, the underlying disease of hyperprolactinemia and associated hormonal changes may have a similar effect as pregnancy and cause SCAD.

There is not a well-established guideline for treatment of SCAD. Studies have demonstrated that SCAD can heal spontaneously in most patients, ranging from 70% to 97% (7). Therefore, SCAD can be managed conservatively as long as the patient is clinically stable. However, in cases of ongoing ischemia or hemodynamic instability, PCI or CABG should be considered. PCI for treatment is associated with an increased risk of iatrogenic dissections or extensions of dissection as a result of underlying arteriopathies (8). The indication for CABG includes left main, proximal left descending artery, or multiple vessel diseases; technical failure or complications of PCI; and refractory ischemia despite conservative management. As a result of subsequent healing of native dissected arteries leading to competitive flow, a high rate of graft occlusions has been reported (8).

**FOLLOW-UP**

The patient was transferred to intensive care unit. Chest closure occurred on post-operative day 2. She was extubated on post-operative day 3 and discharged home on post-operative day 9 without complications. Patient was discharged home on aspirin (81 mg/day), carvedilol (25 mg/day), isosorbide mononitrate (30 mg/day), and rosuvastatin (5 mg/day). Prolactin level during admission was 21 ng/ml (normal range, 2.8 to 29.2 ng/ml). Cabergoline was discontinued and prolactinoma was going to be followed by her endocrinologist.

**CONCLUSIONS**

SCAD commonly occurs in young females without risk factors of atherosclerotic CAD. Although there are multiple factors that could cause SCAD, the use of cabergoline for the treatment of hyperprolactinemia could be related to its incidence. CABG was effective in this symptomatic patient. Further follow-up is necessary to assess long-term outcomes of CABG in SCAD. More recognition about the disease could lead to earlier diagnosis and treatment as well as prevent sudden death.

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KEY WORDS acute coronary syndrome, coronary angiography, coronary artery bypass

APPENDIX For a supplemental video, please see the online version of this paper.
Rotational Atherectomy Induced Coronary Perforation of Right Coronary Artery Draining into Middle Cardiac Vein

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ABSTRACT

Ellis Type III cavity spilling coronary perforation is a rare complication. We report to our knowledge, the first case of rotational atherectomy induced Type III cavity spilling coronary perforation of right posterior descending artery draining into middle cardiac vein, successfully managed by covered stent deployment. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1688-91) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 48-year-old man presented with progressively worsening exertional chest pain and dyspnea, which had been occurring predominantly at rest for the previous 2 weeks.

PAST MEDICAL HISTORY

The patient had a prior history of hypertension, myocardial infarction, and percutaneous coronary interventions in left anterior descending artery, left circumflex artery, and distal right coronary artery (RCA).

LEARNING OBJECTIVES

- To recognize coronary perforation as potential complication associated with rotational atherectomy especially in small arteries.
- To understanding the acute management of Type III cavity spilling perforation.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis for chest pain includes acute coronary syndrome, aortic dissection, pulmonary embolism, panic disorder, and gastroesophageal reflux disease.

INVESTIGATIONS

Physical examination, electrocardiography, and laboratory results, including troponin, were unremarkable. Transthoracic echocardiogram revealed preserved ejection fraction of 60% along with hypokinesis of basal inferior and inferolateral wall. For further evaluation of the unstable angina, the patient underwent invasive coronary angiography via right radial artery. Angiography revealed patent stents in the left anterior descending artery and left circumflex artery, and 70% in-stent restenosis of distal RCA with severely calcified subtotal occlusion of right posterior descending artery (RPDA) (Figure 1A, Video 1).
Given the worsening chest pain, decision was made to proceed with percutaneous coronary intervention. A 6-F internal mammary guide catheter (Mach 1, Boston Scientific, Marlborough, Massachusetts) was used to engage RCA. After successful PTCA to distal RCA in-stent restenosis, a Gaia-2 wire (Asahi Intec, Tokyo, Japan) was used to cross the subtotal occlusion in RPDA with support of a Teleport microcatheter (Orbus Neich, Fort Lauderdale, Florida), which was used subsequently to exchange with a 0.014-inch Run-through wire (Terumo, Tokyo, Japan) after dilation with a 1.0 × 5.0-mm Sapphire II Pro balloon (Orbus Neich). This was followed by serial dilatation with 2.25 × 20-mm noncompliant balloon as well as ath-erotomy with 2.25 × 6.0-mm Wolverine cutting balloon (Boston Scientific) at high pressure; however, there was incomplete balloon expansion in the RPDA lesion (Figure 1B, Video 2) and thus a decision was made to proceed with rotational atherectomy for further plaque modification. The workhorse wire was exchanged with a 0.009-inch RotaWire Floppy (Boston Scientific) using a Teleport microcatheter (Orbus Neich). The 1.25-mm burr was subsequently advanced over the wire to a position proximal to the lesion (Figure 1C). The rotational speed was set at the conventional range (160,000 rotations/min) with a total of 3 runs with each run time <20 s. Post ath-erectomy RCA angiography showed Type III cavity spilling (CS) coronary perforation of RPDA draining into the middle cardiac vein and coronary sinus (Figure 1D, Video 3). The patient remained hemodynamically stable, with no chest pain or electrocardiography changes. Emergent bedside transthoracic echocardiogram excluded any pericardial effusion or tamponade physiology. Anticoagulation (Heparin) was not reversed. The perforation persisted despite prolonged (>12 min) balloon inflation using 2.25 × 20.0-mm noncompliant balloon. Given the extent of perforation, the decision was made to implant a covered stent. A PK Papyrus (Biotronik AG, Bülach, Switzerland) covered stent 2.5 × 15.0 mm was implanted into the RPDA lesion.

**FIGURE 1** Percutaneous Revascularization of RPDA Using Rotablation

(A) Significant in-stent restenosis in distal right coronary artery (RCA) and calcific lesion in right posterior descending artery (RPDA). (B) Undilatable lesion (arrow) in RPDA despite high pressure balloon inflation. (C) A 1.25-mm burr with RotaWire Floppy was used to cross the lesion. (D) RCA angiography showed development of Type III cavity spilling coronary perforation of RPDA draining into the middle cardiac vein and coronary sinus.
deployed in the RPDA, but perforation persisted, as there were multiple jets. Thus, another 2.5 × 15-mm Papyrus stent graft was deployed in RPDA distal to the first covered stent in an overlapping fashion, which successfully sealed the perforation (Figure 2, Video 4).

**DISCUSSION**

We hereby describe a case of rotational atherectomy induced Type III CS coronary perforation (CP) and its acute management.

Ellis classification is the most commonly used classification method of CPs (1). Previous studies have reported combined incidence of all kinds of CPs to be 0.1% to 3.0% (2–5) with reported incidence of Type III CS CP being 3.0% to 3.3% (1,3). Several patient, angiographic, and technical factors, including older age, female sex, Type C lesions, calcified arteries, tortuous and angulated vessels, previous coronary bypass grafts, balloon/stent oversizing, and use of atheroablative devices, have been identified as predictors of CPs (1–5).

Non-CS type III perforations frequently require pericardiocentesis, covered stenting, and/or emergent surgery. On the other hand, type III CS perforations usually have a favorable prognosis, as they seldom lead to acute hemodynamic compromise or ischemia (6,7). In our case, the posterior descending artery (PDA) was a small- to moderate-size vessel that was underfilled due to chronic subtotal occlusion. Considering the lesion under expansion after PTCA and cutting balloon, we decided to proceed with rotational atherectomy for optimal lesion preparation before stent placement. Therefore, a 1.25-mm burr (the smallest available burr) was chosen, and atherectomy was executed considering risks versus benefits involving this small-moderate size vessel. The Intravascular Lithotripsy System (Shockwave Medical, Santa Clara, California) could have been an alternative strategy but was unavailable in our laboratory, so it was not considered. Use of rotational atherectomy in PDA resulted in the dreaded complication of coronary perforation. Although rotational atherectomy in small- to moderate-size vessels can be safely performed in the hands of experienced and skilled operators, the operator should be well prepared and consider these risks. The perforation resulted in a coronary arteriovenous fistula from RPDA to middle cardiac vein draining into the coronary sinus, without hemodynamic instability, or ischemic changes. The middle cardiac vein is one of the coronary sinus tributary veins that arises in the left ventricle apex and travels in the posterior interventricular groove along with the RPDA and drains into the coronary sinus (8).

There is no consensus to manage type III CS perforations, and management of these coronary artery fistulas can be addressed with different approaches. Prolonged perfusion balloon inflation may treat some of them and previous reports have described spontaneous closure of some of these iatrogenic coronary artery fistulas. Patients with these fistulas can remain asymptomatic in 50% to 60% of cases, but can also lead to progressive development of dyspnea and heart failure symptoms when a significant amount of left to right shunt develops over time (8). Considering a large amount of shunt, we decided to proceed with covered stent implantation to seal the perforation after prolonged balloon inflation failed to do so. We used a PK Papyrus covered stent, which provides greater flexibility and smaller crossing profile and successfully sealed the perforation (9,10).

**FOLLOW-UP**

The patient was discharged home the following day after a repeat transthoracic echocardiogram showed preserved ejection fraction and no pericardial effusion. Post-percutaneous coronary intervention peak troponin was 4 ng/ml and peak creatine kinase–MB was 31 IU/L.
CONCLUSIONS

We hereby describe a rare case of rotational atherectomy-associated Type III CS CP of RCA-posterior descending artery draining into the middle cardiac vein and its management.

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KEY WORDS coronary perforation, covered stent, Ellis Type III cavity spilling, middle cardiac vein, rotational atherectomy

APPENDIX For supplemental videos, please see the online version of this paper.
Coronary Artery Aneurysm After Drug-Eluting Stent Implantation Causing Coronary-Bronchial Fistula

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ABSTRACT

Coronary artery aneurysm (CAA) after drug-eluting stent implantation is rare, with a reported incidence of 0.3% to 6.0%. Most of these aneurysms are asymptomatic. Hemothysis as a presentation of CAA is very rare. The patient in our case had CAA after zotarolimus-eluting stent implantation and presented with hemothysis resulting from a leaking coronary-bronchial fistula. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1692–7) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 42-year old man presented to the Base Hospital Delhi Cantt, New Delhi, with a 3-day history of cough, hemothysis, pain in the left lower chest, and generalized weakness, 8 weeks after he underwent left main (LM) coronary artery bifurcation percutaneous coronary intervention (PCI). On admission, the patient’s vital signs were as follows: pulse rate, 84 beats/min; blood pressure, 134/88 mm Hg; and respiratory rate, 16 breaths/min. The patient was afebrile on presentation. The general and systemic examinations were unremarkable.

LEARNING OBJECTIVES

- Consider leaking CAA as a differential diagnosis in patients with hemothysis after DES implantation, so that proper diagnostic and management steps can be taken.
- In patients with CAA as a differential diagnosis, early CT coronary angiography must be planned to identify this serious complication in a timely manner.
- Plan early coronary angiography followed by definitive management in case of a CT angiography result indicative of leaking CAA, so that critical lifesaving time is not lost.

PAST MEDICAL HISTORY

Eight weeks before the current presentation, the patient initially presented to the hospital with anginal chest pain of 10 days’ duration. The electrocardiogram showed ST-segment elevation, T-wave inversion, and poor progression of the R-wave in the anterior chest leads. A 2-dimensional echocardiogram showed left anterior descending (LAD) coronary artery territory hypokinesia with preserved thickness and a 30% ejection fraction. Coronary angiography
showed a dominant, normal right coronary artery, LM distal plaque, LAD osteopropximal plaque followed by thrombotic cutoff, and a nondominant left circumflex (LCX) artery having osteopropximal 60% to 70% stenosis (Figures 1A and 1B, Video 1). He was scheduled to undergo PCI on the LAD through the right radial route. PCI was performed using a 6-F extra back-up guiding catheter. However, the LM artery was dissected with compromised flow to both the LAD and the LCX. The patient became hypotensive, with ongoing angina. Bailout LM bifurcation PCI was performed with the TAP (T and Protrusion) by using Resolute Onyx stents (Zotarolimus-Eluting Coronary Stent System, Medtronic, Minneapolis, Minnesota), 4 × 22 mm from LM to proximal LAD, 3 × 22 mm from proximal to mid-LAD, 2.75 × 22 mm in mid-LAD, 2.75 × 18-mm in osteopropximal LCX, and 2.5 × 18 from LCX to the obtuse marginal major overlapping previous stent. All stents were deployed at 12 atm. Final kissing balloon inflation was done with a 3.5 × 15 mm noncompliant (NC) balloon in the LM to LAD and a 3 × 15 mm NC balloon in the LM to LCX at 10 atm, and the proximal optimization technique in the LM was performed with a 4.5 × 8 mm NC balloon at 20 atm. The patient became angina free and normotensive, with Thrombolysis In Myocardial Infarction (TIMI) flow grade 3 in the left coronary system (Figures 2A and 2B, Video 2). The patient was discharged after 4 days on dual antiplatelet therapy consisting of Ecosprin (a proprietary formulation containing acetyl salicylic acid) and clopidogrel, and he was asymptomatic until his presenting symptoms developed.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis included lung parenchymal infection (bacterial or tubercular), a noninfective lung parenchymal lesion such as a tumor, pulmonary embolism, and coronary artery aneurysm (CAA).

INVESTIGATIONS

The patient’s hematologic and biochemical parameters, as well as his chest radiograph, were normal. A complete blood count showed no leukocytosis, and blood culture showed no growth of organisms. A 2-dimensional echocardiogram showed LAD territory hypokinesia and a 45% ejection fraction. Contrast-enhanced computed tomography (CT) of the chest showed a proximal LCX aneurysm compressing the atrioventricular (AV) junction, a left atrial (LA) and left ventricular (LV) lateral wall intramural hematoma (Figures 3A to 3C), and adjacent lung parenchymal consolidation.

MANAGEMENT

The patient was started on intravenous antibiotics, which resulted in resolution of hemoptysis. Coronary angiography was planned; however, before the procedure, the patient had an episode of massive
hemoptysis and cardiopulmonary arrest. He was revived after 10 min of cardiopulmonary resuscitation. Repeat contrast-enhanced CT of the chest showed air in the ruptured LCX aneurysm and a LA-LV lateral wall intramural hematoma, pneumopericardium, blood in left main bronchus, and air space opacities (Figures 3D to 3F). He was taken for emergency coronary angiography, which showed a

Computed tomography angiography of the thorax and mediastinal window showing (A) a left circumflex (LCX) artery stent in the axial view with an adjacent aneurysm and a large left atrial (LA)-left ventricular (LV) lateral wall intramural hematoma compressing the left atrioventricular (AV) junction in the (B) axial and (C) coronal views. Computed tomography angiography on the day of massive hemoptysis shows the (D) presence of air within the aneurysm and (F) a left atrial-left ventricular lateral wall intramural hematoma. (E) Lung window showing pneumopericardium, a soft tissue density in the left main bronchus suggestive of blood and air space opacities resembling alveolar hemorrhage. These findings were suggestive of ruptured left circumflex aneurysm and its communication with the left main bronchus and left lung. (G) A 3-dimensional reconstruction image showing a left circumflex aneurysm as well as a left circumflex stent. Ao = aorta; LAD = left anterior descending artery.
ruptured fusiform aneurysm in the proximal LCX artery that was bleeding into the left pleuropulmonary space (Figures 4A and 4B, Video 3). The LM artery was hooked with a 7-F extra back-up catheter, both LAD and LCX were wired, and a plan was made to place a covered stent across the bleeding aneurysm. However, because of high flow from the ruptured site, the LCX wire went into the pleuropulmonary space (Figure 4C, Video 4) and could not be negotiated to the distal LCX. Because of continuous bleeding, the patient was hemodynamically unstable, and a 4 × 19 mm covered stent (Graftmaster, Abbott Vascular, Santa Clara, California) was placed from the LM to the LAD across e LCX, thereby controlling the LCX leak. The patient’s hemodynamic status improved after the intervention. Thereafter, the patient developed generalized tonic-clonic seizures secondary to hypoxic-ischemic encephalopathy, bleeding gastric ulcers, ventricular-associated pneumonia, and right lung collapse, and he was treated with intravenous antiepileptic agents, endoscopic hemoclips, upgraded antibiotics, and bronchoscopy, respectively. The patient remained critically ill, with ongoing hypoxic-ischemic encephalopathy, a poor Glasgow Coma Scale score, ventricular-associated pneumonia, and sepsis. Five days post-aneurysm rupture, the patient had a sudden cardiac arrest and died of his illness. Autopsy revealed a 1.5 × 1.5 cm pseudoaneurysm around the proximal LCX stent with an adjacent 5.2 × 5.8 cm intramural hematoma in the LA and LV lateral wall compressing the left AV junction (Figures 5A and 5B). The ruptured aneurysm was also seen to be communicating with left main bronchus and left lung parenchyma through a fistula between the wall of the left atrium and the lower lobe of the left lung. The LCX artery showed overlapping in situ metallic stents in its lumen with aneurysmal dilation. The histopathology report found sections from the LA and LV walls showing intramural hematomata. Sections of the LA and LV walls had features of old myocardial infarction with granulation tissue and fibrosis, with spaying of cardiac myocytes. Sections from the LCX artery showed a dilated lumen with an atheroma within the wall of the coronary artery. There was disruption of the tunica intima and underlying media with adherent thrombus suggestive of a pseudoaneurysm. The absence of significant inflammation of the vessel wall ruled out the presence of a mycotic aneurysm.

**DISCUSSION**

CAAs after PCI are rare (incidence, 0.3% to 6.0%), and most of these lesions are pseudoaneurysms (1-3). CAA after PCI has been reported with bare-metal stents (BMS), as well as with drug-eluting stents (DES) (2). Mechanisms of CAA after PCI include coronary dissection and medial injury resulting from the use of oversized balloons or stents, high-pressure balloon inflation, atherectomy, and laser angioplasty (1-3). CAA is seen more commonly with DES as compared with BMS (2). DESs elute antiproliferative drugs to prevent restenosis; however, this may also delay coronary healing. In addition to this mechanism, medial inflammation secondary to a hypersensitivity reaction to the drug, polymer, or stent platform may also predispose patients to CAA formation after DES implantation (4-6). This complication is more frequently seen after bailout or complex coronary procedures. In this case, a pseudoaneurysm...
developed across the LCX stent after bailout LM bifurcation PCI with a zotarolimus-eluting stent. In addition, the possibility of extension of the LM dissection to the LCX, as well as balloon dilatation or coronary wire-induced medial injury and intimal dissection, could not be ruled out. These mechanisms, in conjunction with the antiproliferative action of the DES, could explain the formation of the pseudoaneurysm. Although most CAAs are asymptomatic, presentation secondary to ischemia caused by aneurysmal thrombosis or distal embolization can occur (7,8), and rupture of CAAs, albeit rare, may lead to ischemia and life-threatening tamponade (7,9,10). Hemoptysis as a presentation of CAA, as seen in this case, is rarely reported. The aneurysm across the LCX stent gradually eroded the pericardium, left pleural membrane, and left lung parenchyma to communicate with airways and leading to hemoptysis. Rupture of the CAA led to massive hemoptysis, hemopneumopericardium, pneumomediastinum, left hemopneumothorax, and air space hemorrhage. Management of CAAs depends on presentation, rate of expansion, size, and evidence of infectivity. Asymptomatic, small CAAs can be managed medically with dual antiplatelet agents (8). Percutaneous interventions for symptomatic aneurysms include covered stent implantation (as done in this case), as well as balloon or stent-assisted aneurysmal coil embolization (8). Giant CAAs (>20 mm), CAAs involving the LM artery, and infective aneurysms require surgical excision and coronary artery bypass (2,8). This report was approved by the institutional ethical committee of Base Hospital Delhi Cantt, New Delhi.

CONCLUSIONS

Although CAAs are relatively rare complications of PCI, they can have disastrous complications. The presence of atypical presentations such as hemoptysis in a post-PCI patient should not preclude this diagnosis, especially in patients who underwent complicated or bailout PCI. Hence, in such patients, CAAs should be kept in the differential diagnosis. Early CT angiography must be planned because the presence of an aneurysm warrants urgent coronary angiography and definitive management.

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KEY WORDS complication, coronary angiography, percutaneous coronary intervention

APPENDIX For supplemental videos, please see the online version of this paper.
ABSTRACT

Woven coronary artery anomaly is a rare congenital anomaly, and intravascular ultrasound and optical coherence tomography are useful for the diagnosis. We performed both imaging techniques for woven coronary artery anomaly and evaluated which was superior. We concluded that optical coherence tomography was the preferred imaging modality in this case. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1698-9) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 68-year-old man with a history of hypertension, dyslipidemia, and previous myocardial infarction involving the right coronary artery had exertional chest pain and was admitted for percutaneous coronary intervention to treat residual stenosis of the left anterior descending artery. On admission, his vital signs were normal. The electrocardiogram showed pathological Q waves in his inferior leads. Coronary angiography before percutaneous coronary intervention showed a small, twisting channel around the left anterior descending lesion (Figure 1A). The differential diagnosis of this channel included a bridging collateral vessel, recanalized thrombus, spontaneous coronary dissection, or woven coronary artery anomaly (WCAA).

We performed both intravascular ultrasound (IVUS) and optical coherence tomography (OCT) to evaluate this channel. IVUS showed an additional lumen connecting to the distal lumen of the main vessel (Video 1). OCT demonstrated the extra lumen more clearly (Video 2). Bridging collateral vessels develop in chronic total occlusions, but in this case the coronary artery was not occluded. If this channel had been caused by recanalized thrombus, the extra lumen should have been present within the coronary lumen. IVUS appeared to show that the extra lumen was outside the tunica media, but it was unclear (Figure 1B). OCT demonstrated that the lumen was clearly outside the tunica media (Figure 1C). The IVUS appearance could have been consistent with intramural hematoma (Figure 1D), which is occasionally observed in spontaneous coronary dissection, but we were unable to demonstrate an intimal tear with OCT (Figure 1E). On the basis of the OCT findings, we confirmed that the correct diagnosis was WCAA. A drug-eluting stent was implanted (Figure 1F), and both IVUS and OCT showed a well-deployed stent with a diminished additional lumen (Videos 3 and 4).

WCAA is a very rare congenital anomaly that is usually considered benign, and accurate diagnosis is difficult to establish. IVUS and OCT are useful for the diagnosis (1,2), but few reports have used both techniques to
determine which is superior for the diagnosis of WCAA. In this case report, OCT was superior to IVUS for confirming the presence of WCAA.

This patient remained symptom free during 1-year follow-up.

In conclusion, OCT was better for the diagnosis of WCAA when we detected an abnormal structure around a coronary artery.

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ABBREVIATIONS AND ACRONYMS

IVUS = intravascular ultrasound

OCT = optical coherence tomography

WCAA = woven coronary artery anomaly

FIGURE 1 Imaging of WCAA

(A) Coronary angiogram before stent implantation (arrows show the small, twisting channel). (B) Extra lumen (asterisks) outside the vascular lumen seen on intravascular ultrasound. (C) Extra lumen (asterisks) outside the vascular lumen seen on optical coherence tomography. (D) Extra lumen (asterisk) outside the vascular lumen seen on intravascular ultrasound. (E) Extra lumen (asterisk) outside the vascular lumen seen on optical coherence tomography. (F) Coronary angiogram after stent implantation (arrows show the small, twisting channel).

WCAA = woven coronary artery anomaly.
Deferred Intravascular Lithotripsy-Facilitated Stenting in ACS
Novel Approach to Improve PCI Outcomes in Severe Calcification?

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ABSTRACT

Moderate/severe calcification, present in approximately one-third of culprit lesions in acute coronary syndromes (ACS), portends unfavorable procedural and post-primary percutaneous coronary intervention outcomes. Intravascular lithotripsy is a novel technique using shockwaves to fracture calcific plaques. Presenting a clinical case, we enumerate efficacy and safety parameters in using intravascular lithotripsy in ACS. (Level of Difficulty: Advanced.)

Moderate/severe calcification, present in approximately 30% of culprit lesions in acute coronary syndromes (ACS) (1), adversely affects safety/efficacy of primary percutaneous coronary intervention (PCI) and portends worse post-PCI outcomes (1). Although atherectomy is contraindicated in thrombotic coronary lesions, intravascular lithotripsy (IVL) may mitigate the adverse consequences of severe calcification (2). IVL, however, has not been tested in ACS and DISRUPT-CADIII trial (Disrupt CAD III With the Shockwave Coronary IVL System; NCT03595176), designed for premarketing approval of coronary IVL, has excluded patients with ACS.

An alternative approach for PCI on severely calcified culprit lesions was undertaken in a 65-year-old woman with inferior ST-segment elevation myocardial infarction (STEMI) (Figure 1). IVL use was approved by the institutional review board at our institution.

Safety of IVL in thrombus-laden lesions is unknown. Insonification of platelet/fibrin-rich thrombi by shockwaves may result in thrombus degradation/embolization. Shockwaves can induce myocardial depolarization (2). Although an R-on-T phenomenon inducing tachyarrhythmia has not been substantiated in
stable coronary lesions (2), such a risk in electrically excitable myocardium during early reperfusion is unknown. Thus, “off-label” IVL use in acute STEMI is not recommended.

We propose that IVL can be used in staged stenting procedure during which thrombus burden and myocardial electrical instability may be substantially less. This approach is supported by the DEFER-STEMI (Deferred Stent Trial in STEMI), in which deferring stent implantation in STEMI resulted in reduced no-reflow and increased myocardial salvage, with approximately 4% needing urgent PCI before the staged procedure (3).

**FIGURE 1** Staged Intravascular Lithotripsy-Facilitated Stent Deployment in STEMI

(A) A 65-year-old woman presented with inferior STEMI. Heart rate = 70 beats/min and blood pressure = 110/60 mm Hg. (B) High-pressure noncompliant balloon inflation failed to dilate the severely calcified culprit lesion (arrowheads). TIMI flow grade 3 was achieved, and stenting was deferred. (C) At a staged procedure, a 3 × 12-mm IVL balloon was inflated (4 atm) and 3 cycles of IVL delivered. Post-IVL, full balloon inflation was noted. (D) Post-IVL IVUS revealed multiple fractures in the concentric calcification (arrows). (E) A 3 × 23-mm drug-eluting stent was implanted and post-dilated with a 3.5 × 20-mm noncompliant balloon (at 22 atm). Final angiography revealed optimal stent expansion and TIMI flow grade 3. (F) IVUS MSA = 7.9 mm². No slow-flow/no-reflow, arrhythmia, or hemodynamic compromise were noted during the staged procedure. Ca = calcium; IVL = intravascular lithotripsy; IVUS = intravascular ultrasound; MSA = minimal stent area; NC = noncompliant; TIMI = Thrombolysis In Myocardial Infarction.

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**KEY WORDS** acute coronary syndromes, intravascular lithotripsy, percutaneous coronary intervention, plaque calcification
Circumflex Artery Arising From the Pulmonary Artery
Always a Malignant Coronary Anomaly?

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ABSTRACT

Some coronary artery anomalies are associated with increased risk of sudden cardiac death and myocardial infarction in young patients. There are few data on the clinical and prognostic relevance of isolated origin of the left circumflex artery from the pulmonary artery, an extraordinarily rare variant of anomalous left coronary artery from the pulmonary artery.  

(History of Presenting): A 39-year-old man was admitted to the emergency department with long-lasting palpitations preceded by abdominal pain, vomiting, and diarrhea. At presentation, the patient was afebrile and hemodynamically stable, with an unremarkable physical examination. The electrocardiogram (ECG) showed sinus rhythm without ST-segment deviation. There was no alteration in blood test results despite a slightly elevated C-reactive protein. In serial determination of markers of myocardial damage, there was an elevation of high-sensitivity troponin I (5.28 ng/ml).

Past Medical History

The patient had aortic coarctation partially corrected during childhood with a bypass between the left subclavian artery and the descending thoracic aorta. He underwent reoperation with a Hemashield (Maquet, Rastatt, Germany) aortic graft implantation at 24 years of age. Follow-up cardiac magnetic resonance confirmed a good result of the aortic graft but significant stenoses at the proximal and distal...
anastomosis of the subclavian-to-aortic bypass (Figures 1A and 1B). He was previously diagnosed with type 1 bicuspid aortic valve with normal function (Video 1). He had no known cardiovascular risk factors.

Differential Diagnosis

In this scenario, different entities must be considered in the presence of elevated troponin, such as myocarditis or acute myocardial infarction type 1 or type 2.

Investigations

First, a transthoracic echocardiogram demonstrated normal left ventricular ejection fraction with no wall motion abnormalities (Videos 2, 3, and 4), bicuspid valve normal function (Video 5), and absence of recoarctation (Video 6, Figure 2). Because of his previous symptoms of viral infection, cardiac magnetic resonance was requested to rule out myocarditis, and the imaging showed not only normal left ventricular systolic function but also no edema (Video 7) or fibrosis (Video 8). To complete the differential diagnosis, cardiac computed tomography angiography was performed. This technique demonstrated the presence of left circumflex artery origin from the pulmonary artery (LCxPA) (Video 9, Figures 3A and 3B) without significant stenosis (Figure 3C). Small aortobronchial fistulous communications (Figure 3D) were noted as remnants of aortic coarctation. Finally, invasive cardiac catheterization confirmed the diagnosis by showing that the left circumflex artery had good retrograde filling through collateral vessels from the left anterior descending and right coronary arteries (Videos 10 and 11).

Management

During hospitalization, no arrhythmias were detected in continuous ECG monitoring. In the absence of chest pain or new clinical events, the patient was considered at low risk for sudden cardiac death (SCD). He was conservatively managed and discharged to be closely followed.

Follow-Up

The patient has been followed up for 1 year. A recent treadmill test with single-photon emission computed tomography with sestamibi was informed as clinical and ECG negative but showed mild basal inferolateral ischemia on perfusion imaging (Figures 4A and 4B). Given the absence of symptoms and the limited perfusion defect, expectant management was maintained.

Discussion

The clinical implications of LCxPA are not well established. Garcia et al. (1) first described it in adults in 1992, in a patient with no other congenital heart disease (CHD) who reported dyspnea and chest pain at rest. Recently, few additional cases have been described in adults: 2 presented as SCD, 1 with double-outlet right ventricle (2), and 1 without CHD (3), and another patient presented with mild exertional chest pain, wall motion abnormalities noted on echocardiography, and aortic coarctation (4). In contrast, in the larger experience with LCxPA among pediatric patients (5-7), the presentation was mostly exertional chest pain and dyspnea, and the association with other CHDs was higher. Two main questions arise from the scarce data described in published reports. First, given the higher life expectancy of patients with CHD nowadays, coronary anomalies, and this anomaly in particular, should be considered in the differential diagnosis of exertional symptoms or SCD. In this regard, noninvasive imaging techniques comprise the first diagnostic approach, requiring also invasive angiography in some cases, which enables physicians to: 1) assess adequate retrograde flow from collateral vessels; and 2) have a basal angiogram for comparison in the middle to long term in case the patient presents with extensive myocardial ischemia. In contrast, there are no consensus and guidelines defining the management of LCxPA. Although the latest guidelines (8) recommend surgery for asymptomatic anomalous left coronary artery from the pulmonary artery, they do not specify guidance on variants such as LCxPA; therefore, the only evidence is based on case reports. In these cases, adult patients presented with resting angina, dyspnea, New York Heart Association functional class III or IV, or aborted cardiac death in shockable rhythm were surgically treated. Only 1 reported patient (9) had angina and no pathological findings on ECG or echocardiography but was surgically treated. However, most of the adults described in published reports have had no previous heart operations (3,5-7,9,10). Besides, survival depends on collateral development (5,9),

Abbreviations and Acronyms

CHD = congenital heart disease
EGC = electrocardiogram
LCxPA = left circumflex from the pulmonary artery
SCD = sudden cardiac death
FIGURE 2 Doppler Echocardiography of the Descending Aorta

Peak systolic velocity is 161 cm/s, and peak systolic gradient is 10 mm Hg.

(A) Volume-rendering technique. (B) 2-dimensional magnetic resonance angiography. Mild dilatation of ascending aorta (white arrows), subclavian-descending aorta bypass (blue arrows) with stenosis at the proximal and distal anastomoses. Permeable Hemashield (Maquet, Rastatt, Germany) graft (asterisks).
and surgery is recommended when symptoms are
attributed to ischemia (10). Conversely, our patient
reported palpitations with no chest pain on admis-
sion, and although findings of single-photon emission
computed tomography with sestamibi were slightly
positive for ischemia, the treadmill test result was
clinically negative at high load, and he remained free
from angina during follow-up. This patient had
considerable collateralization, 2 previous thoracic
surgical procedures, and symptoms that could be
attributed to supraventricular tachycardia triggered
by relative hypovolemia secondary to gastroenteritis.
After careful consideration, we chose conservative
management and close follow-up. Certainly, we
cannot ensure completely the appropriateness of our
management. Nonetheless, we present the case of a
patient who, more than a year after the diagnosis, has
no symptoms or cardiovascular rehospitalizations.
This outcome supports medical treatment as an op-
tion in selected scenarios.

**CONCLUSIONS**

LCxPA is a rare coronary anomaly, but it has been
described in association with CHD, especially aortic
coarctation. Awareness of this entity will enable early
diagnosis and provide potential prognostic benefit. Furthermore, there is a gap of evidence regarding the best treatment of this anomaly. Although cardiac surgery has been extensively used, our case shows that conservative management may be an option in some circumstances.

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KEY WORDS ALCAPA, anomalous circumflex artery, coronary anomaly sudden cardiac death

APPENDIX For supplemental videos, please see the online version of this paper.
Acute Myocardial Infarction With Cardiogenic Shock Due to Pericardial Constriction and Multivessel Coronary Obstruction

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ABSTRACT

We present a rare case of cardiogenic shock and multivessel coronary compression due to focal pericardial inflammation and constriction. The patient was treated in the acute phase with coronary stenting and temporary mechanical support. Multimodality imaging was essential in elucidating the diagnosis. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1708–12) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 62-year-old woman awoke from sleep with acute-onset chest pressure. In the emergency department, her blood pressure was 83/63 mm Hg, and an electrocardiogram (ECG) showed ST-segment elevation consistent with an infero-posterolateral myocardial infarction (Figure 1).

PAST MEDICAL HISTORY

There was history of rheumatoid arthritis and an episode of pericarditis 4 years prior, with pericardial tamponade requiring a pericardial window. There were no coronary artery disease risk factors.

DIFFERENTIAL DIAGNOSIS

Because of diffuse ST-segment elevations on the ECG and shock, the patient was brought emergently to the cardiac catheterization lab.

INVESTIGATIONS

Coronary angiography revealed acute total and subtotal occlusions of the left anterior descending artery, first diagonal, and 3 obtuse circumflex branches.
The coronary occlusions were in the mid to distal portions of each vessel, linearly at nearly identical distances from the left main. There was no evidence of thrombus or of intracoronary plaque. The 5 narrowed coronary artery segments resembled spasm, yet there was no response to intracoronary nitroglycerin. There was a dynamic component to the occlusions with the disappearance of several coronary artery segments only during systole (Video 1).

**MANAGEMENT**

Because of cardiogenic shock, a transvalvular left ventricular support device (Impella CP, Abiomed, Danvers, Massachusetts) was placed, and the patient was intubated. She underwent stenting of the LAD and obtuse marginal (OM) 2 and balloon angioplasty of OM1. Stented segments remained patent, but the ballooned vessel continued to exhibit dynamic narrowing after angioplasty, as did the untreated OM3 and diagonal branches.

The patient was transferred to the cardiac care unit, where she was extubated and weaned from mechanical support after 1 day. Twenty-four hours later, she complained of recurrent chest discomfort, which was associated with new ST-segment elevations. She was taken back for cardiac catheterization and underwent stenting of OM1 (Figure 2), upon which her symptoms improved and ST-segments normalized. Left ventriculography demonstrated mild to moderate left ventricular dysfunction with apical and anterolateral akinesis. Peak troponin I level was 8.9 ng/ml.

After stabilization, echocardiogram showed asymmetric pericardial thickening and a wall motion abnormality in the posterolateral wall (Figure 3). Because of concern that there was extrinsic pericardial scarring affecting coronary flow, coronary computed tomography angiography was performed, which demonstrated pericardial thickening and coronary stents that were bent at acute angles as if externally compressed (Figure 4). Cardiac magnetic resonance imaging (MRI) demonstrated delayed gadolinium enhancement of the anterior and lateral pericardium as well as enhancement and edema on T2 short tau inversion recovery sequences (Figure 5), which suggests active pericarditis.

**DISCUSSION**

We identified 2 prior case reports of multivessel coronary obstruction occurring in the setting of pericardial calcification. Bhagia et al. (1) described a man with presumed prior tuberculous pericarditis who later developed unremitting angina from severe LAD obstruction caused by focal calcified...
pericardial constriction. Angina was relieved with partial pericardiectomy. Similarly, Gaur et al. (2) described a man with chronic rheumatoid arthritis who developed LAD obstruction secondary to focal calcific pericardial band and was treated with percutaneous coronary intervention. In both of these cases, pericardial calcification was identified by chest x-ray or computed tomography scan.

Hsi et al. (3) described a case of multivessel coronary constriction due to a focal pericardial band in the absence of calcification. A woman with prior pericardial window for pericardial effusion due to chest wall trauma from basketball developed cardiac arrest and multivessel myocardial infarction. The obstructions all occurred in a linear pattern as if constricted externally by a fibrous band. All vessels demonstrated

**FIGURE 2** Second Cardiac Catheterization for Recurrent Chest Pain

The second cardiac catheterization performed for recurrent chest pain: stent placed to OM1 during this procedure. Narrowing can be seen in the stents to OM1, OM2, and the LAD.

D = diagonal; LAD = left anterior descending artery; OM = obtuse marginal.
Thrombolysis In Myocardial Infarction flow grade 3, so the patient underwent multimodality imaging before coronary stenting to determine the etiology of the occlusions.

We describe, to our knowledge, the first case of cardiogenic shock and multivessel infarction requiring emergent percutaneous coronary intervention and advanced mechanical support due to presumed noncalcified pericardial thickening and tethering with secondary coronary compression. We suspect that the initial trigger may have been recurrent but asymptomatic pericardial inflammation, as demonstrated on subsequent MRI, along with pre-existing extensive pericardial scarring and adherence to the epicardium. We speculate that this inflammation formed a pericardial band that was capable of generating enough force to compress multiple coronary arteries and stents. Because of intermittent coronary compression and immediate intervention, the infarction size was small, with relatively low troponin levels and absence of subendocardial enhancement on MRI. Interestingly, in the case of focal pericardial constriction described by Bhagia et al. (1), coronary compression was also...
intermittent and occurred only during systole, as in our case.

**FOLLOW-UP**

The patient remained chest pain free after stenting and was discharged home with colchicine, dual anti-platelet therapy, angiotensin-converting enzyme inhibitor, and beta blocker. She remained chest pain free at the 2-month follow-up. Her rheumatologist has added a nonsteroidal anti-inflammatory medication to treat the pericarditis. Follow-up echocardiography showed normalization of left ventricular systolic function.

**CONCLUSIONS**

Focal pericardial constriction and coronary compression is a rare cause of acute multivessel myocardial infarction and cardiogenic shock. Multimodality imaging is helpful in the diagnosis of this entity.

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**KEY WORDS** 3-dimensional imaging, acute coronary syndrome, cardiac assist devices, computed tomography, echocardiography, MR sequences, percutaneous coronary intervention.

**APPENDIX** For supplemental videos, please see the online version of this paper.
Pulmonary Embolism After Vaginal Delivery in a Fontan Patient

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ABSTRACT

The Fontan procedure was created to address the mixing of pulmonary and systemic venous return in patients with a single functional ventricle. The patient in this case with a Fontan repair experienced multiple pulmonary emboli 10 days post-partum. We outline management and recommendations when treating these patients. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1713-5) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

PRESENTATION

This patient was a 20-year-old single pregnancy (G1) with viable offspring (P1) and 1 abortus (001) status post vacuum-assisted vaginal delivery at 39 weeks. During her pregnancy, she was receiving amoxicillin prophylaxis for asplenia prophylaxis, 250 mg daily, and aspirin, 81 mg daily. Her peripartum period was complicated by presumed chorioamnionitis/endometritis and was treated with ampicillin, gentamicin, and clindamycin. Additionally, she had a post-partum hemorrhage with estimated blood loss of 3 liters and underwent a dilation and curettage due to concern for retained products. She was discharged 4 days post-partum with plans for follow-up in 2 weeks. She presented 10 days post-partum with shortness of breath and right-sided chest tightness which worsened with inspiration since the previous day. Upon arrival she was hypoxic with O₂ saturation of 50% to 60% and tachycardia above 150 beats/min. Physical examination revealed labored breathing and decreased breath sounds in the lower lung lobes bilaterally.

MEDICAL HISTORY

This patient had a history of heterotaxy syndrome (right isomerism type) with a double-inlet left ventricle, multiple ventricular septal defects, pulmonary atresia, and bilateral superior vena cava status post Fontan procedure. Her surgical history included a Blalock-Taussig shunt, bilateral Glenn anastomosis, and lateral tunnel fenestrated Fontan, followed later by a percutaneous closure of the Fontan fenestration. Echocardiography showing normal

LEARNING OBJECTIVES

- To recognize increased risk for VTE in Fontan patients in pregnancy.
- To discuss current guidelines for VTE prevention in Fontan patients and pregnancy.
systolic function and mild atrioventricular valve regurgitation was noted in the first and third trimesters.

**DIFFERENTIAL DIAGNOSIS AND INVESTIGATIONS.**

Given the patient’s medical history of a Fontan procedure and her presentation of acute, pleuritic chest pain with low oxygen saturation upon admission, it was suspected that the patient experienced a pulmonary embolism (PE). Peripartum cardiomyopathy and acute myocardial infarction were also considered as possible diagnoses. Upon arrival, a complete blood count, complete metabolic panel, brain natriuretic peptide, and troponin level tests were ordered. Troponin concentration was normal; brain natriuretic peptide was elevated (133.1 pg/ml), but peripartum cardiomyopathy was ruled out because chest radiography results were negative for cardiomegaly, infiltrates, and pleural effusion. Her chest computed tomography scan result was positive for nearly occlusive emboli within the right lower lobar artery and a nearly occlusive thrombus in the right upper lobar artery (Figure 1). Multiple smaller thrombi were noted. Transthoracic echocardiography demonstrated no pericardial effusion and no abnormal left ventricular function. Lower extremity Doppler readings were negative.

**MANAGEMENT.** Therapeutic enoxaparin was administered prior to her computed tomography scan due to the presumed diagnosis of PE. On the second day of admission, she underwent left heart catheterization for evaluation of Fontan hemodynamics and cardiac output in the context of large clot burden. She also underwent right heart catheterization and placement of Ekos catheters (Coloplast, Fredensborg, Denmark) bilaterally in the right and left main pulmonary arteries with alteplase (tissue plasminogen activator) for 12 h. The Ekos catheters were removed on the second post-operative day, and daily warfarin, 5 mg, was started. She was discharged home on hospital day 5 on 2 L of oxygen with 6 months of anticoagulation therapy on warfarin with bridging with enoxaparin with the INR value goals of 2 to 3.

**DISCUSSION**

The Fontan procedure addresses the mixing of pulmonary and systemic venous return in patients with a single functional ventricle (1). The procedure redirects blood returning from the systemic circulation from the superior and inferior vena cavae to the pulmonary arteries, thereby bypassing the right ventricle (2). Pregnancy increases risk of

**FIGURE 1 Maximum Intensity Projection Computed Tomography Images**

Coronal (A) and sagittal (B) maximum intensity projection computed tomography images demonstrate filling defects in bilateral lower lobar and segmental and right middle lobe segmental pulmonary arteries, consistent with acute thromboemboli. The examination was performed in the equilibrium phase, given the history of prior Fontan palliation.
thromboembolic events as it induces a hypercoagulable state (3,4). These changes may not normalize until 8 weeks after delivery and lead to an increased risk of arterial and venous thromboembolism (VTE) during pregnancy and post-partum (3).

Previous studies indicate a prevalence for thromboembolic events in Fontan patients of 1% to 30% (5). However, guidelines for anticoagulation in Fontan patients are evolving (5). One study showed no significant differences in thromboembolic events for Fontan patients treated with antiplatelet therapy compared to well-regulated anticoagulation therapy (5). American Heart Association guidelines recommend antiplatelet therapy after the Fontan procedure but anticoagulation only in high-risk patients (6). European Society of Cardiology guidelines indicate that Fontan pregnancies are moderate to high risk for thromboembolism and that anticoagulation should be considered (7).

In a study by Pundi et al. (8), 70 pregnancies were reported in Fontan patients. Although patients in that cohort experienced other complications, none experienced thromboembolic events during pregnancy, despite the fact that only 63% of patients in that cohort were taking anticoagulation therapy, and 16% were taking antiplatelet therapy (8). The present study also used Ekos catheters to treat PE in the present patient. A study by McCabe et al. (9) demonstrated the effectiveness of Ekos catheters for treatment of PE. In that study, 53 patients with PE were treated using ultrasonography-assisted catheter-directed thrombolysis. Patients experienced reductions in pulmonary artery pressures after the procedure (9).

**FOLLOW-UP**

Within a month of follow-up, the present patient discontinued use of home oxygen as she had reached her baseline in the low 90s. Her warfarin dosage was adjusted to 6.5 mg daily to reach her INR goal of 2 to 3. Six months into warfarin therapy, she stopped breastfeeding and was transitioned to apixaban, 5 mg twice daily. Although evidence for the use of apixaban for recurrent PE prophylaxis is limited, a study by Georgekutty et al. (10) indicated that apixaban can be effective in Fontan patients with a history of thrombosis.

**CONCLUSIONS**

Although the present patient was treated during pregnancy with low-dose aspirin in accordance with American Heart Association guidelines, she experienced post-partum pulmonary emboli. Current guidelines from the European Society of Cardiology suggest anticoagulation should be considered in Fontan patients during pregnancy if there are other risk factors for VTE. Similarly, American Heart Association guidelines recommend that anticoagulation should be considered in Fontan patients who are at-risk (see discussion above). The venous stasis that occurs in the single ventricle along with the increased thrombotic risk during the pregnancy, specifically in the post-partum period, suggests that the Fontan may itself be a significant risk factor for VTE. The present case report adds to the studies of risk for VTE in patients with Fontan and pregnancy. In patients without contraindications, prophylactic anticoagulation may be considered for Fontan patients at 36 weeks’ pregnancy and for 12 weeks’ post-partum.

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**KEY WORDS** congenital heart defect, pregnancy, thrombus
Williams Syndrome and Neonatal Cardiac Surgery for Congenital Single Ventricle

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ABSTRACT

Williams syndrome (WS) is an arteriopathic derangement associated with supravalvular aortic stenosis and branch pulmonary stenosis. We describe double-outlet right ventricle with mitral atresia and aortic arch hypoplasia in an infant with WS. This case demonstrates the difficulty in managing patients with WS with complex cardiac defects. To our knowledge, this is the first reported single-ventricle physiology in a patient with WS. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1716–9) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A female infant was born at 37 weeks of gestation. Apgar scores were 8 and 9 at 1 and 5 min, respectively. Prostaglandin E1 infusion was started at delivery due to a fetal echocardiogram demonstrating congenital heart disease and concern for inadequate systemic blood flow with aortic arch hypoplasia. The infant was transferred to the neonatal intensive care unit from the outside hospital immediately after delivery.

Birth weight and length were 2.68 kg (25th percentile) and 45 cm (<3rd percentile), respectively. Heart rate was 168 beats/min with respiratory rate 45/min. Oxygen saturation was 90% and 86% in the right arm and right leg, respectively. Blood pressure was 60/28 and 46/33 mm Hg in the right arm and leg, respectively. Physical examination demonstrated typical findings of Williams syndrome (WS), including a short upturned nose, epicanthal folds, periorbital edema, right ear lower than left, and long philtrum. Cardiac examination revealed a quiet precordium with prominent S2, systolic ejection click, and grade II/VI systolic ejection and II/VI diastolic murmurs.

There was moderate cardiomegaly on chest x-ray with an upturned apex, abdominal situs solitus, and normal thymic shadow. Electrocardiogram showed low atrial rhythm with narrow QRS duration and right

LEARNING OBJECTIVES

- To identify cardiovascular complications associated with WS and recommended components of screening.
- To recognize challenges associated with single-ventricle physiology in conjunction with WS.
ventricular hypertrophy. In the first 24 h of hospitalization, the patient developed respiratory acidosis and required endotracheal intubation.

**PRENATAL HISTORY**

Pregnancy was complicated by intrauterine growth restriction. Initial prenatal echocardiogram at 29 weeks of gestation was diagnostic for double-outlet right ventricle (DORV), malposition of the great arteries, large subpulmonary ventricular septal defect, confluent branch pulmonary arteries, and severe coarctation (Figure 1, Videos 1 and 2). Prenatal chromosomal microarray revealed a 1.48 megabase interstitial deletion at chromosome 7q11.23, consistent with WS. Family history was unremarkable for cardiovascular disease and congenital anomalies.

**DIFFERENTIAL DIAGNOSIS**

Congenital heart defects occur in approximately 80% of patients with WS, with supravalvular aortic stenosis and peripheral pulmonary artery stenosis occurring most frequently, although Tetralogy of Fallot, complete atrioventricular septal defect, total anomalous pulmonary venous return, double-chambered right ventricle, and Ebstein anomaly of the tricuspid valve also have been reported (1). Based on this patient’s prenatal echocardiogram, differential diagnosis included severe unbalanced atrioventricular septal defect with atresia of the left atrioventricular valve and DORV with mitral valve atresia.

**INVESTIGATIONS**

Transthoracic echocardiogram on the first day of life (DOL) confirmed atrial situs solitus, atrioventricular concordance with mitral atresia, a single ventricle of right ventricular morphology, DORV, and malposition of the great arteries (pulmonary artery anterior and to the left) with large subpulmonary ventricular septal defect. The inferior vena cava connected to the right atrium; there were bilateral superior vena cavae, without bridging vein. The main pulmonary artery (MPA) was of normal diameter, but the right branch pulmonary artery (RPA) and left branch pulmonary artery (LPA) were relatively hypoplastic (RPA 3.2 mm [z-score, –1.8]; LPA 3.0 mm [z-score, –2.3]). The semilunar valves were normal with a tri-leaflet...
Williams Syndrome

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Head ultrasound demonstrated normal structures. Renal ultrasound demonstrated no evidence of renal artery stenosis. Hypoplastic tricuspid valve and mild-to-moderate tricuspid valve regurgitation. Coronary arteries were of normal origin. A large ductus arteriosus was present with right-to-left flow. Renal ultrasound demonstrated no evidence of renal artery stenosis. Head ultrasound demonstrated normal structures.

MANAGEMENT

On DOL 4, the patient underwent surgical aortic arch reconstruction with patch augmentation of the ascending aorta, atrial septectomy, tricuspid valve commissurotomy, banding of the MPA, and ligation/division of the ductus arteriosus on cardiopulmonary bypass. Postoperatively, desaturation episodes required increased supplemental oxygen and intermittent intervention with manual ventilation (post-operative day [POD 9]). Frequent echocardiogram assessments demonstrated effective MPA band gradients, but on POD 10 there was an increase in velocity in the RPA (maximum 4.6 m/s). On DOL 15 (POD 11), the patient returned to the operating room where ductal tissue impinging the branch pulmonary arteries was excised, the MPA band was revised, and bilateral proximal patch pulmonary arterioplasty was performed. During subsequent hospital course, effective MPA band gradient was documented using echocardiogram (3.5 m/s).

Despite acceptable echocardiogram findings, the patient developed hypotension and anasarca, which was refractory to medical management. Cardiac catheterization was performed on DOL 26. Direct pulmonary venous saturations were 93% to 95%. Index cardiac output was decreased at 2.2 l/min/m², with Qp:Qs of 1.5:1. Mean right atrial pressure was 15 mm Hg, without significant gradient across the atrial septum. Peak right ventricular (RV) systolic pressure was 100 mm Hg, with an increased RV end-diastolic pressure of 17 mm Hg. There was a peak gradient of 45 mm Hg across the pulmonary artery band, with a distal MPA pressure of 55/15 mm Hg. Additional pressure gradient was seen into the bilateral branch pulmonary arteries, with distal LPA pressure of 29/12 (mean, 22) mm Hg and distal RPA pressure of 17/13 (mean, 15) mm Hg. Ascending aortic pressure was 80/32 mm Hg, demonstrating a RV to aortic peak instantaneous gradient of 20 mm Hg. There was no additional gradient by pullback through the aortic arch. Indexed pulmonary vascular resistance on room air was 2.1 WU/m².

Angiography demonstrated mild dilation of the transverse aorta that was consistent with the surgical patch augmentation (Videos 3 and 4); however, brachiocephalic branching demonstrated generally hypoplastic vessels with a distally displaced left subclavian artery. The descending aorta was diffusely hypoplastic, but without discrete stenosis. The RV demonstrated vigorous RV systolic function, without significant tricuspid valve insufficiency. On lever-phase, pulmonary veins returned normally to the left atrium. Pulmonary arteriography demonstrated good band position with hypoplastic branch pulmonary arteries without discrete branch pulmonary artery stenosis; however, RPA and LPA remained hypoplastic (RPA 3.1 mm [z-score, –2.3]; LPA 3.1 mm [z-score, –2.5]).

Despite the cardiac surgical repair, the patient required escalating intensive care for worsening renal function and abdominal ascites. An intracranial hemorrhage occurred, necessitating an Ommaya reservoir to relieve intracranial pressure. The patient developed metabolic acidosis, systemic hypotension, and refractory hypoxemia.

DISCUSSION

WS results from a sporadic deletion encompassing the elastin gene, resulting in diffuse arterial stiffness from hypertrophy of arterial walls with consequent luminal narrowing (2-4). Elastin creates recoil potential within blood vessels. The resulting deficiency of elastin leads to increased stiffness within vascular structures (2). In general, patients with WS with outflow tract obstruction, ventricular hypertrophy, or coronary ostial stenosis are at highest risk of cardiovascular complications and death (5). Current guidelines recommend that all patients with WS undergo cardiovascular screening with examination by a pediatric cardiologist, including 4-extremity blood pressure and transthoracic echocardiogram. Renal ultrasound with Doppler is routinely obtained to screen for renal artery stenosis. Progressive arterial narrowing is well recognized (1).

In the case presented, postoperative renal and intracranial complications presented significant post-operative comorbidity. Balanced pulmonary and systemic arterial blood flows were demonstrated using hemodynamic catheterization. A mild obstruction was present between the ventricle and the ascending aorta,
although further intervention typically is reserved for more severe obstruction in patients with WS (6).

Distal arterial changes are difficult to quantify, particularly in the neonate with WS. Despite adequate surgical palliation of single ventricle anatomy, diffuse arteriopathy likely contributed to post-operative complications in this neonatal case. Imaging of renal, coronary, mesenteric, and intracranial arteries might be performed at preoperative baseline using various modalities, including ultrasound with Doppler, computed tomography, and/or magnetic resonance imaging angiography; however, specific risk stratification is not yet available for patients with WS in relation to the size of extracardiac vascular structures and interrogation of peripheral arterial/venous flow (5).

**FOLLOW-UP**

Despite aggressive inotropic and metabolic support, the patient showed minimal improvement and the decision was made to withdraw life-sustaining treatment.

**CONCLUSIONS**

This case illustrates potential difficulties that may be encountered in neonates with complex cardiac anatomy and known diffuse arteriopathy. Arteriopathy associated with WS may increase postoperative risk after palliative cardiac surgery, where balanced, unobstructed systemic and pulmonary arterial blood flow are critical. This risk must be considered when discussing surgical intervention with families of patients with WS.

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**KEY WORDS** aortic arch hypoplasia, congenital heart disease, genetic syndrome, pulmonary artery stenosis

**APPENDIX** For supplemental videos, please see the online version of this paper.
Giant Pulmonary Artery Aneurysm in Bicuspid Pulmonary Valve
Does the Right Side Mimic the Left One?

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ABSTRACT

Bicuspid pulmonary valve is a rare echocardiographic finding, particularly if not associated with other congenital heart diseases. We report the incidental case of a severe giant pulmonary arterial aneurysm associated to bicuspid pulmonary valve in an asymptomatic 79-year-old patient. Multimodality cardiac imaging was important for the correct diagnosis and to exclude any other potential complication. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1720–2)

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Aortic and pulmonary valves are known to stem from the same embryonic arterial trunk, and this could explain the similar presentation of some types of congenital defects in both of the 2 valves. However, due to the limited number reported, more in autopsic analysis, little is known about the effective risk and management of pulmonary abnormalities. Multimodality cardiac imaging is mandatory to better define the valve morphology and to rule out related complications. Overall, surgery remains the cornerstone of therapy, albeit definite surgical thresholds are still lacking.

CASE REPORT

A 79-year-old patient presented to the emergency department for fever and chest pain, described as breathing and cough variable and almost continuous for weeks. No previous cardiovascular history was known, except for arterial hypertension treated with calcium antagonist therapy. A transthoracic echocardiogram performed to investigate a systolic murmur showed a moderately stenotic pulmonary valve and severe pulmonary artery aneurism (PAA) (Figures 1A and 1B, Videos 1 and 2). Noninvasive estimation of pulmonary artery pressure resulted in the normal range. The chest pain was explained by a pleuritic inflammation detected at chest x-ray, and a urine test revealed an infection treated with antibiotics. A computed tomography (CT) scan was urgently performed to rule out any acute emergency, although the patient never reported any symptoms related to the PAA compression. The CT and the 3-dimensional CT reconstruction confirmed these data (Figures 1C and 1D, Video 3), as far as the magnetic resonance imaging (Figure 1E, arrow; Videos 4, 5, 6, and 7).

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors’ institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the JACC: Case Reports author instructions page.

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Balancing potential risks and benefits, corrective heart surgery had been proposed to the patient, but was rejected in the absence of symptoms. Currently, after 3 years of follow-up, she is asymptomatic, taking bisoprolol 5 mg/die and routinely transthoracic echocardiogram has been scheduled every 6 months.

**FIGURE 1** Patient’s TTE, CT, and CMR

**(A and B)** Patient’s transthoracic echocardiogram (TTE). The pulmonary trunk was severely dilated (maximum diameter of 6.39 cm), with severe dilatation of the pulmonary arteries (2.97 and 2.8 cm, respectively). The pulmonary cusps appeared myxomatous and calcific. The maximum velocity recorded was 2.98 m/s with a maximum gradient $>35$ mm Hg. 

**(C and D)** Patient’s computed tomography scan (CT). The CT confirms the presence of a severe dilation of the PA trunk (6.7 x 5.9 cm), right pulmonary artery (3.8 x 3.5 cm), and left pulmonary artery (3.6 x 3.4 cm) with no sign of dissection of the wall. The pulmonary valve appeared morphologically bicuspid. The 3-dimensional CT reconstruction confirmed the severe dilatation of the pulmonary trunk and pulmonary arteries. 

**(E and F)** Patient’s cardiac magnetic resonance imaging (CMR). The pulmonary valve appeared morphologically bicuspid, and the presence of a severe dilation of the PA trunk and pulmonary arteries was confirmed.

**ABBREVIATIONS AND ACRONYMS**

CT = computed tomography scan  
PAA = pulmonary artery aneurysm
DISCUSSION

Bicuspid pulmonary valve is an exceedingly rare finding usually associated with PAA that could result as the consequence of chronic stenosis of the valve. Few sporadic cases of PAA have been reported until now, especially concerning autopic analysis, but such a giant PAA with bicuspid pulmonary valve in an asymptomatic woman has never been described. Moreover, as demonstrated here, a multimodality imaging approach was crucial to better define the morphology of the pulmonary valve, to exclude any other congenital defects, such as conotruncal anomalies, and to rule out any associated complications. Different cutoffs for PAA have been proposed, from a range of 26.9 mm in women (1) to 29 mm (2) in the general population, and an absolute diameter ≥55 mm has been designated for surgical intervention (3); so our case, where PAA was 64 mm, was clearly enclosed in these ranges. Overall, surgery remains the cornerstone of these pulmonary abnormalities; however, there are no clear guidelines yet on the optimal management of these patients (4). In our case, the absence of complications and symptoms has leaded the patient to give up the proposed corrective surgery, so we have planned a follow-up every 6 months. Moreover, albeit not clearly specified, a pharmacological treatment with beta-blockers has been introduced to reduce vascular wall stress, as is usually also done for the aneurisms of the aortic tract.

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KEY WORDS bicuspid pulmonary valve, congenital disease, giant aneurism, pulmonary artery

APPENDIX For supplemental videos, please see the online version of this paper.
When “Blue Babies” Grow Up
Complications After Surgical Repair of Tetralogy of Fallot

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ABSTRACT

Tetralogy of Fallot (TOF) is a complex congenital cardiac defect. Surgical correction is well established as the treatment of choice and has resulted in a rapidly growing group of adults living with TOF. We describe potential complications of patients who have undergone TOF repair and were lost to follow-up. (Level of Difficulty: Intermediate.)

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Tetralogy of Fallot (TOF) is a rare and complex congenital cardiac defect that alters the normal flow of blood through the heart. The 4 main characteristics of TOF are a large ventricular septal defect (VSD), pulmonary stenosis, right ventricular (RV) hypertrophy, and an overriding aorta. These defects must be repaired with open heart surgery soon after birth or relatively early in infancy to allow for increased longevity and survival into adulthood (1,2). Although there have been advances in medical therapy over the last 2 decades, continued lifelong care from specialists is essential because long-term heart problems resulting from the original repair are common (Table 1).

HISTORY OF PRESENTATION

A 44-year-old white woman with a history of TOF at birth underwent a left-sided Blalock-Taussig shunt in the neonatal period followed by complete repair at the age of 3 years. She presented to our community-based multidisciplinary adult congenital heart disease clinic to establish care with a local cardiologist after she was noted to have a markedly abnormal electrocardiogram and an enlarged heart on a chest radiograph during an urgent care visit for an upper respiratory infection (Figures 1 and 2). Her cardiac examination revealed a mildly enlarged heart

LEARNING OBJECTIVES

• To recognize the importance of long-term surveillance in patients with adult congenital heart disease, such as TOF.
• To identify major long-term complications of TOF.
• To be familiar with guidelines for evaluation and management of TOF.
• To recognize the most common surgical procedures appropriate for management of TOF and symptomatic relief.
to palpation with an RV lift. The first heart sound was normal, whereas the second heart sound had a slightly wide split. There was a grade 2/6 short, low-pitched systolic ejection murmur that was loudest at the mid-upper left sternal border with slight radiation to the posterior lung fields, as well as a grade 2/6 low-pitched diastolic murmur in the same region.

PAST MEDICAL HISTORY

The patient is an active smoker who recently relocated. She saw her adult congenital heart disease specialist 3 years earlier and needed to establish care with a local cardiologist. As a child, she was advised to avoid overexertion with physical activities and thus did not participate in competitive sports. However, she otherwise denied any limitations when playing with other children. She gave birth to 1 child without complications.

INVESTIGATIONS

At the time of her initial evaluation within our clinic, she denied any active symptoms. A baseline transthoracic echocardiogram (TTE) was obtained and showed evidence of a VSD repair and a dilated right ventricle with mildly decreased function. There was no evidence of pulmonary hypertension despite mild to moderate tricuspid regurgitation and pulmonary regurgitation (PR). She had done well over the years until she was found to have unprovoked bilateral pulmonary emboli and right lower extremity deep vein thrombosis 2 years after the initial visit with us. Results of an extensive hypercoagulable work-up were negative. As part of her work-up, she underwent an esophagogastroduodenoscopy and colonoscopy along with advanced imaging that demonstrated a mass in the cecum. The patient had subsequent episodes of venous thrombosis and was placed on lifelong anticoagulation with rivaroxaban 20 mg daily. TTE was obtained during her admission, and severe PR and RV dilation were noted. Cardiac magnetic resonance (CMR) confirmed severe PR (regurgitation fraction 46%) and an RV end-diastolic volume index of 218 ml, with an RV ejection fraction of 40% (Figures 3A to 3D).

MANAGEMENT

The patient was sent to her pediatric cardiac surgeon because of severe right-sided heart enlargement, moderate tricuspid regurgitation, and severe PR for redo sternotomy with pulmonary valve replacement (PVR) using an Edwards No. 27 Magna-Ease bioprosthetic valve (Edwards Lifesciences, Irvine, California) and tricuspid valve repair using an Edwards No. 32 annuloplasty ring. She had no perioperative or post-operative complications. A repeat TTE post-operatively demonstrated mild PR with normal antegrade flow. The patient was doing well and was asymptomatic for 6 to 9 months post-redo sternotomy with a PVR and tricuspid valve replacement before she started having worsening fatigue, fluid retention, and dyspnea. Post-operative TEE showed thickening and restricted mobility of the medial leaflet of the Magna-Ease valve without significant flow obstruction and a maximal velocity of 2.14 m/s. Repeat cardiac magnetic resonance showed severe PR (regurgitation fraction 45%), an RV ejection fraction of 44%, and an RV end-diastolic volume index of 161 ml. The patient appeared to have rapid deterioration of her bioprosthesis valve, suspected to be secondary to thrombosis caused by a lack of compliance and a questionable coagulopathy (Figures 4A to 4D).

| TABLE 1 | Relevant Guidelines for TOF Recommendation |
|----------------|------------------------------------------|
| COR | LOE | Guidelines |
| I | B-NR | CMR can help quantify ventricular size and function, pulmonary valve function, pulmonary artery anatomy, and left-sided heart abnormalities in patients with repaired TOF. |
| I | B-NR | PVR (surgical or percutaneous) can relieve symptoms in patients with repaired TOF and moderate or greater PR with unexplained cardiovascular symptoms. |
| IIb | C-EO | PVR may be considered for preservation of ventricular size and function in asymptomatic patients with repaired TOF and ventricular enlargement or dysfunction with moderate or greater PR. |
| IIa | B-NR | Surgical PVR may be considered for adults with repaired TOF and moderate or greater PR, with other lesions requiring surgical interventions or ventricular tachyarrhythmias. |

CMR = cardiac magnetic resonance; COR = Class of Recommendation; LOE = Level of Evidence; PR = pulmonary regurgitation; PVR = pulmonary valve replacement; TOF = tetralogy of Fallot.
She reported extreme fatigue and dyspnea on minimal exertion. It was believed that the bioprosthetic valve dysfunction was significant enough to recommend placement of a transcatheter valve within the failing bioprosthetic pulmonic valve (Figure 5). A Melody valve (Medtronic, Minneapolis, Minnesota) was believed to be preferable because of a better flow profile and possibly less of a tendency to thrombosis. Table 2 shows the chronological sequence of these complications in a patient post-TOF repair and the subsequent management strategies used.

DISCUSSION

After surgical repair, a marked improvement can be expected in the patient’s functional class and quality of life; however, careful follow-up is required to monitor for residual hemodynamic abnormalities (3). Many patients are asymptomatic through early adulthood, and that is why many are lost to follow-up and miss the opportunity to identify and treat long-term complications of TOF before these conditions become irreparable (4). Conversely, a significant number of patients with TOF will develop progressive RV dysfunction from residual pulmonary insufficiency or stenosis (5). It is crucial that primary care physicians and local cardiologists know how to recognize signs and symptoms of a worsening condition and make timely referrals to tertiary adult congenital cardiology clinics for further evaluation and management.

The most frequent problem that occurs after TOF repair is pulmonary backflow (4). This can have detrimental effects on RV function and can lead to irreversible RV decompensation, arrhythmias, and subsequently higher mortality rates (3,4). Patients
present with palpitations, exertional dyspnea, right-sided heart failure, and syncope during later stages\(1,4\). A low-pitched diastolic murmur may be heard along with a pansystolic murmur if a residual VSD is present\(4\). Electrocardiograms commonly show RV hypertrophy with a right bundle branch block\(3,4\). A larger RV volume and mass are often seen with a longer QRS complex duration, which when longer than 180 ms is strongly associated with ventricular arrhythmias and sudden death\(4\). Chest radiography will show cardiomegaly and a prominent right ventricle; however, a CMR is the gold standard for evaluating RV size and function, as well as PR\(6\). Baseline CMR is recommended even for asymptomatic patients (Table 1)\(4,6\).

Our patient required reintervention for severe pulmonary insufficiency. PVR is the standard of care and is expected to decrease both RV end-diastolic

![Image of CMR Demonstrating Severe Pulmonary Regurgitation](image)

**FIGURE 3 CMR Demonstrating Severe Pulmonary Regurgitation**

Images showing a regurgitation fraction of 46%, a right ventricular end-diastolic volume index of 218 ml, and a right ventricular ejection fraction of 40%. (A) Sagittal view. (B) Short-axis view demonstrating large right ventricle. (C) Coronal view of pre-operative large right ventricle. (D) 3-dimensional cardiac magnetic resonance (CMR) showing a large right ventricle. A = axis; HL = head left obliquity; I = inferior; L = left; LV = left ventricle; R = right; RV = right ventricle; S = superior.
volume and RV end-systolic volume, as well as an increase in corrected RV ejection fraction, subsequently improving patient symptoms, which can be objectified using the New York Heart Association functional classification (1–3). Studies have shown that the rates of PVR in adults with TOF have doubled over the past decade (7). This trend likely reflects evidence on the consequences of PR and strategies to optimize timing of PVR (7). Improvements in surgical technique and the availability of percutaneous valves have led to a growing group of adults with TOF. We as physicians must provide post-operative care to these patients and must learn to recognize the deleterious effects associated with this condition.

**FOLLOW-UP**

The patient had undergone placement of a Melody transcatheter pulmonary valve that appeared to be normal with unobstructed movement, with a peak gradient across the valve of 15 mm Hg and mild pulmonary insufficiency indicating excellent results (Figure 6).

**FIGURE 4** Repeat Cardiac Magnetic Resonance of Post-Operative Complications

Images showing severe pulmonary regurgitation (regurgitation fraction 45%), right ventricular ejection fraction of 44% and right ventricular end-diastolic volume index of 161 ml. (A) Short-axis view in systole. (B) Short-axis view in diastole. (C) Axial view in systole. (D) Axial view in diastole. H = head.
FIGURE 5 Initial Pressures and Saturations Obtained as Detailed on the Diagram

Arrows indicate catheter course.

TABLE 2 Management of TOF: A Timeline of Key Events

| Birth | TOF Diagnosed |
|-------|---------------|
| Neotal period | Blalock-Taussig shunt undertaken |
| Age 3 yrs | Complete TOF repair |
| Age 6 yrs | Delivered of a healthy child without complications |
| Age 26–43 yrs | No subsequent cardiac complications or procedures |
| Age 43 yrs | Initial hospital admission: Presented with shortness of breath and found to have bilateral PE and DVT |
| | • Experienced 30-lb weight loss over 6 months |
| | • Hypercoagulable work-up initiated, including endoscopy and colonoscopy → found to have cecal mass |
| | • Managed with oral anticoagulation (rivaroxaban) |
| | • Residual cardiac findings: |
| | ◦ TTE showed severe RV enlargement with mildly reduced RV function. |
| | ◦ Moderate tricuspid regurgitation, severe pulmonary valve regurgitation seen on TTE and confirmed by CMR (RF 46%, RVEDV 218 ml/m², RVESV 131 ml/m²). Also seen in CMR is a severely enlarged RV outflow tract and main pulmonary artery. 4 months later: |
| | • Underwent PVR with Magna-Ease 27-mm bioprosthetic valve (Edwards Lifesciences, Irvine, California) and TV repair with an Edwards No. 32 annuloplasty ring |
| | • Post-operative TTE at 2 months and 6 months showed improvement with a moderately enlarged RV cavity and mild tricuspid and pulmonary valve regurgitation |
| Age 44 yrs | 10 months after PVR and TV repair |
| | • Patient presented to the emergency department for right-sided back pain |
| | • TTE during admission demonstrated moderate TV regurgitation and mild to moderate pulmonary valve regurgitation; evidence of thickening of the bioprosthetic valve leaflets is noted, dilated IVC of 21–22 mm 1yr after PVR and TV repair |
| | • Follow-up CMR showed severe pulmonary valve regurgitation (RF 45%, RVEDV 161 ml/m², RVESV 91 ml/m²) with an RVEDV index of 161 |
| | • Patient experiencing extreme fatigue, fluid retention, and dyspnea with minimal exertion indicating early failure of surgical bioprosthetic pulmonary valve with severe pulmonary insufficiency |
| | • Underwent successful placement of 22-mm Melody (Medtronic, Minneapolis, Minnesota) transcatheter pulmonary valve |

CMR = cardiac magnetic resonance; DVT = deep vein thrombosis; IVC = inferior vena cava; PE = pulmonary embolism; PVR = pulmonary valve replacement; RF = regurgitation fraction; RV = right ventricular; RVEDV = right ventricular end-diastolic volume; RVESV = right ventricular end-systolic volume; TOF = tetralogy of Fallot; TTE = transthoracic echocardiogram; TV = tricuspid valve.
CONCLUSIONS

Advances in diagnosis, medical management, and surgical repair of TOF have markedly improved prognosis and resulted in long-term survival. This success, however, presents unique challenges as functional capacity considerably improves and duration of follow-up increases. It is crucial that these patients be monitored closely by an adult congenital cardiac specialist or by a trained general cardiologist who is able to identify residual abnormalities and development of comorbidities.

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KEY WORDS adult congenital heart disease, complications, follow-up, pulmonary valve replacement, tetralogy of Fallot
MINI-FOCUS ISSUE: CONGENITAL HEART DISEASE

CASE REPORT: CLINICAL CASE

Transcatheter Aortic Valve Replacement in a Patient With Levo-Transposition of the Great Arteries

Eric Kellett, MD, Scott Lilly, MD, PhD, Curt Daniels, MD, Saurabh Rajpal, MD

ABSTRACT

Levo-transposition of the great arteries is a congenital heart disease characterized by atrioventricular and ventricular-arterial discordance. Aortic valve disease in levo-transposition of the great arteries patients is uncommon. We present a patient with levo-transposition of the great arteries and severe aortic stenosis who successfully underwent transcatheter aortic valve replacement and the diagnostic and procedural challenges involved. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1730–3) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 63-year-old White man with history of levo-transposition of the great arteries (LTGA) presented with progressive fatigue and shortness of breath for the last several months. He denied lower extremity edema, palpitations, dizziness, lightheadedness, or syncope. His vitals included heart rate of 90 beats/min, blood pressure of 114/63 mm Hg, and respiratory rate of 16 breaths/min. On examination, he had a grade III/VI systolic ejection murmur over the upper sternal border and a grade II/VI pansystolic murmur over the left lower sternal border.

PAST MEDICAL HISTORY

The patient was diagnosed with LTGA during childhood and followed with a cardiologist. He did not have any other cardiac anomalies associated with LTGA, such as ventricular septal defect, pulmonic stenosis, or tricuspid valve dysplasia (1,2). His only surgical history was dual-chamber pacemaker placement for complete heart block 10 years ago. He was on rivaroxaban for paroxysmal atrial fibrillation. The patient had a history of rheumatic fever as a child but no records were available for review. A transthoracic echocardiogram (TTE) done 2 years prior showed normal biventricular function, aortic sclerosis, and mild aortic stenosis. Other noncardiac history included obstructive sleep apnea on continuous...
positive airway pressure, type II diabetes mellitus, and hyperlipidemia.

**DIFFERENTIAL DIAGNOSIS**

LTGA is characterized by an acyanotic functional reversal of the right and left ventricles in the sequence of blood flow so that systemic venous “blue” blood via right atrium and left atrioventricular (mitral) valve reaches the right-sided morphologic left ventricle, which is connected to the pulmonary artery; the pulmonary venous “red” blood via the right atrioventricular (tricuspid) valve reaches the left-sided morphologic right ventricle, which is connected to the anteriorly placed aorta. The differential diagnosis for dyspnea on exertion and fatigue in an adult patient with LTGA includes:

- **Systemic ventricular dysfunction.** Studies have shown that by the age of 45 years, 67% of patients with associated congenital lesions and 25% of patients without associated congenital lesions develop systemic ventricular dysfunction (3). Our patient did not have an associated causative congenital lesion and last echo showed normal systolic function.

- **Systemic atrioventricular (tricuspid) valve regurgitation.** Studies have shown that 32% of patients with LTGA develop moderate to severe right atrioventricular (tricuspid) valve regurgitation by age 45 years (3).

- **Ischemic heart disease.** Coronary artery disease is not uncommon in patients with congenital heart disease and risk factors (4,5). Our patient had advanced age plus multiple risk factors, thus ischemic heart disease was in our differential.

- **Complication of chronic arrhythmia and long-term pacing.** Retrospective studies have found univentricular pacing in patients with LTGA can be complicated by delayed systemic ventricular dysfunction. Biventricular pacing is preferred because it reduces late-onset complications (6).

- **Severe aortic stenosis.** Although aortic regurgitation has been shown to occur in roughly 25% patients with LTGA (3), aortic stenosis has been reported only in the setting of coexistent bicuspid aortic valve (4). Our patient did not have a bicuspid aortic valve.

**INVESTIGATIONS**

Electrocardiogram showed atrial-sensed ventricular-paced rhythm unchanged from prior. TTE (Videos 1A and 1D) showed moderately reduced systemic ventricular function (right ventricular ejection fraction, 35% to 40%) and subpulmonic ventricular function (left ventricular ejection fraction, 40%). There was mild tricuspid regurgitation (Video 1B). The aortic valve was thickened and calcified with reduced mobility (Videos 1C and 2A). Two-dimensional and Doppler findings were consistent with low-flow low-gradient aortic stenosis (Figure 1, Video 1E). The peak gradient was 33 mm Hg with a mean gradient of 19 mm Hg. Coronary angiogram demonstrated mild nonobstructive coronary artery disease.

Based on the elevated Doppler gradient and aortic valve appearance on TTE we suspected that his aortic valve stenosis could be clinically and hemodynamically significant. Therefore, we elected to perform a hemodynamic catheterization at rest and with dobutamine to evaluate for low-flow low-gradient aortic stenosis.

Hemodynamic catheterization demonstrated an aortic valve gradient of 28 mm Hg, Fick cardiac output of 4.2 l/min, and aortic valve area of 0.9 cm² per the Hakki equation (7). With dobutamine 20 μg/kg/min, the aortic valve gradient increased to 39 mm Hg, cardiac output increased to 4.8 l/min, and aortic valve area remained 0.9 cm². This demonstrated that with increasing cardiac output the aortic valve gradient increased 2-fold, whereas the aortic valve area remained in the severe range, confirming

**ABBREVIATIONS AND ACRONYMS**

- **LTGA** = levo-transposition of the great arteries
- **LVOT** = left ventricular outflow tract
- **RVOT** = right ventricular outflow tract
- **TAVR** = transcatheter aortic valve replacement
- **TTE** = transthoracic echocardiogram
the diagnosis of low-flow low-gradient aortic stenosis.

**MANAGEMENT**

The patient was assessed in our adult congenital heart disease and interventional cardiology clinics. Based on the presence of symptomatic severe low-flow low-gradient aortic stenosis, we recommended aortic valve replacement and referred to cardiothoracic surgery. He was deemed a high surgical risk because of severe biventricular dysfunction. After discussion in the multidisciplinary case conference, plans were made for transcatheter aortic valve replacement (TAVR). Computed tomography angiography for TAVR evaluation was performed, which showed calcific valvular aortic stenosis with restricted leaflet mobility (Video 2B).

With pre-procedural planning with computed tomography and transesophageal echocardiography guidance intraprocedurally, the patient underwent placement of Medtronic 34 CoreValve Evolute R (Minneapolis, Minnesota) via right iliofemoral approach and tolerated the procedure with no complications.

**DISCUSSION**

There are several characteristics that make this case unique. First, aortic stenosis in LTGA is rare and has not been reported in the absence of bicuspid aortic valve (5). We suspect this aortic stenosis may have been caused by the patient’s history of rheumatic fever as a child. Patients with LTGA typically develop failure of the systemic tricuspid valve and systemic ventricular dysfunction (3).

Diagnosis was also challenging because of poor echocardiographic windows and complex anatomy. Moreover, because the LTGA aortic valve is in the right ventricular outflow tract (RVOT) instead of the left ventricular outflow tract (LVOT), we could not calculate aortic valve area using the continuity equation because it relies on geometric assumptions for the LVOT but not the RVOT (8). The RVOT is comparatively more muscular, more variable, and more contractile than the LVOT. In addition, it is difficult to obtain an accurate RVOT diameter on TTE.

TAVR placement in the RVOT is also uniquely difficult. The RVOT has a much larger area and more significant variance throughout systole and diastole than the LVOT. Because of the close proximity of the aortic valve and tricuspid valve, tricuspid regurgitation is a concern. Furthermore, the levorotation of the heart and anteriorly placed aorta makes catheter manipulation atypical, with the levo-transposition yielding a high risk of atrioventricular block. Finally, LTGA is frequently associated with coronary anomalies, so the valve placement must consider altered coronary anatomy as well.

Despite the challenges of placing a transcatheter aortic valve in the RVOT, with careful pre-procedural planning our outcome was excellent. In our literature search we could find only 1 report of TAVR placement in the RVOT of an LTGA patient, although in that case the patient did not survive to 1-year post-operation (9).

**FOLLOW-UP**

As of most recent follow-up 12 months post-operative, the patient has done well with improved functional capacity back to baseline. Follow-up TTE was performed, which showed improved systemic right ventricle ejection fraction of 55% and estimated mean gradient of 8 mm Hg, with only trivial tricuspid valve regurgitation.

**CONCLUSIONS**

TAVR was successful in our patient with LTGA with improvement in symptoms, functional capacity, and echocardiographic measures of systemic and subpulmonic ventricular function without worsening of systemic tricuspid valve function. TAVR can be used as a strategy in LTGA patients who are at high risk of surgery.

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KEY WORDS aortic valve stenosis, congenital heart defect, echocardiography, levo-transposition of the great arteries, transcatheter aortic valve replacement

APPENDIX For supplemental videos, please see the online version of this paper.
Limited arterial vascular access precluded necessary transcatheter intervention in a 22-year-old woman with repaired interrupted aortic arch type B. Alternative transcaval vascular access enabled percutaneous therapy. This practice evolution is likely to benefit the growing numbers of adults with congenital heart disease. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1734–5) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Caval-aortic or transcaval access is performed for adults with limited transfemoral artery vascular options (1,2), and it should be considered for comparable patients with adult congenital heart disease (ACHD). A 22-year-old woman with ACHD characterized by interrupted aortic arch type B was originally managed with a surgical 10-mm aortic isthmus jump graft and a subsequent surgical 16-mm Gore-Tex (W.L. Gore and Associates, Newark, Delaware) ascending-to-descending aorta bypass graft. She developed a compressive seroma around the 16-mm graft that prompted consideration for transcatheter management. Femoral artery access for transcatheter endograft was aborted because the required 16-F sheath could not traverse 3.9-mm and 1.5-mm vessels; the subclavian arteries were occluded. Patients with ACHD who present again decades after initial palliation may require unique management solutions, including establishment of sufficient vascular access to permit transcatheter therapy.

We pursued alternative transcaval vascular access (Figures 1A to 1F). Pre-procedural comprehensive advanced imaging (including peripheral access vessels) for pediatric patients with congenital heart disease is not systematic. As our case illustrates, it should be common practice in patients with ACHD and was performed before the subsequent transcaval procedure.

As previously described, transcatheter electrosurgery with an electrified 0.014-inch guidewire (Astato XS 20, Asahi, Tustin, California) supported in a NaviCross catheter (Terumo, Somerset, New Jersey) and a 6-F IM guide catheter (Cordis, Santa Clara California) was performed to cross from the vena cava to the aorta (2). Subsequent standard transcaval access enabled introduction of a 20-F aortic sheath (Gore DrySeal Flex, Gore) (1,2). Although pre-procedure cardiac computed tomography (CT) overlay is not required, we find it helpful for intraprocedural transcaval access. A thoracic endovascular graft (24 mm × 105 mm; Zenith Alpha Thoracic Endovascular Graft, Cook Medical, Bloomington, Indiana) followed by a bare-metal stent (36 mm; IntraStent Max LD, Covidien, Plymouth, Minnesota) excluded the extravascular communication and eliminated...
compressive obstruction. A ductal occluder (Amplatzer Duct Occluder 8 to 6 mm, Abbott, Abbott Park, Illinois) closed the tract post-intervention. Post-tract closure angiography demonstrated hemodynamically insignificant type 1 (tubular aorto-caval fistula) closure (1). Balloon tamponade and covered stent options were available if required. In our initial experience, conservative follow-up imaging was performed the following day, at 1 month, and then at 6 months post-procedure. The fistula was occluded at 6 months by contrast-enhanced CT (Video 1).

**FIGURE 1** Transcaval Access for Transcatheter Congenital Heart Disease Intervention

(A) Pre-procedure cardiac computed tomography reconstruction demonstrates a compressive seroma (arrow) around a previous surgical Gore-Tex (W.L. Gore and Associates, Newark, Delaware) aortic arch bypass graft (asterisk) from the ascending aorta (AAo) to the descending aorta (DAo). (B) Limited femoral artery vascular access prompted (C) transcaval access with the snare in the descending aorta and wire crossing (arrow), including computed tomography overlay. (D) Post-endograft exclusion (arrow) and bypass graft dilation (asterisk) and (E) standard transcaval closure were performed (arrow). (F) At 6-month follow-up abdominal computed tomography (no residual fistula) is shown.

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**KEY WORDS** adult congenital heart disease, congenital heart disease, endovascular, transcatheter electrosurgery, transcaval access

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**ABBREVIATIONS AND ACRONYMS**

ACHD = adult congenital heart disease

CT = computed tomography

**APPENDIX** For supplemental videos, please see the online version of this paper.
ABSTRACT

In a 32-year-old patient with chest pain, a large, complex coronary-venous fistula with additional feeders from the descending aorta was detected with computed tomography. Multimodality imaging, including multicolor 3-dimensional printing, allowed precise anatomic visualization of the origin, course and drainage site of the fistula. The patient was treated conservatively. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1736–8) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 32-year-old patient presented with acute chest pain, diffuse ST-segment elevation on the electrocardiogram, and elevated cardiac troponin. Coronary angiography excluded stenosis of the epicardial vessels but showed an ectatic left main coronary artery with suspicion of a coronary fistula (Figure 1A, Video 1).

For better anatomic visualization and assessment of hemodynamic significance a cardiac computed tomography (CT) scan was performed. A large coronary-venous fistula (maximum diameter 8 mm) arising from the proximal circumflex artery, running between the left ventricular outflow tract and the anterior wall of the left atrium and draining into the superior vena cava, was shown (Central Illustration A, Figure 1B, Video 2). In addition, a small vessel originated from the descending aorta and bifurcated into 2 branches: 1 running superior and 1 inferior to the left pulmonary artery (Central Illustration B, Figure 1C, Video 3). The 2 branches rejoined and drained into the distal part of the coronary-venous fistula. For further spatial assessment of the complex vessel anatomy a multicolor 3-dimensional (3D) printed model, using binder-jetting technology, was created (Figure 1D, Video 4). This technology allows creating a multicolored 3D model, while also identifying small substructures such as the fistula origin and adjacent arteries, which would be essential for a safe interventional or surgical treatment (1). A coronary aneurysm or dilatation of right chambers, as indirect sign of hemodynamic relevance, could be excluded. Furthermore, echocardiographically, there was no evidence of an elevated pulmonary artery pressure; a cardiac magnetic resonance scan showed a pattern of acute myocarditis without evidence of myocardial infarction with normal biventricular dimensions, equal and normal.
biventricular stroke volumes, as well as aortic and pulmonary flow volumes. Therefore, the patient was treated conservatively.

DISCUSSION

Coronary fistulae are rare, primarily congenital abnormal communications between coronary arteries and another cardiovascular structure without an interposed capillary bed ranging from 0.05% to 0.9% in several large selected series (2). Clinically, the drainage site of a fistula is more important than its origin; coronary cameral fistulae terminate in a cardiac chamber (commonly into low-pressure right-side cardiac structures), and coronary arteriovenous fistulae terminate into a venous structure such as venae cavae, coronary sinus, bronchial veins, and pulmonary arteries (2).

Recent guidelines have toned down indications for surgical or interventional repair and considered the elevated risk (11%) of post-operative myocardial infarction, for example, due to slow flow phenomenon in the dilated coronary artery proximal to the fistula, coronary dissection, or spasm, as well as thrombosis or device embolization leading to a reduced late survival (3). In general, presence of large, symptomatic coronary fistulae—with evidence of ischemia by steal phenomenon—require review by a knowledgeable multidisciplinary heart team to determine the role of medical therapy and/or percutaneous or surgical closure (3). Most coronary fistulae, however, are small, do not compromise myocardial blood flow, and are incidental findings.

Multiplanar reconstruction with 3D volume-rendered imaging yields precise anatomic visualization of the size, origin, course and drainage site of the fistula; 3D printing may enhance visuospatial appreciation of the vascular anomaly, in particular with cases of complex anomalies with tortuosity, multiple origin, and drainage sites. A tangible heart model by 3D printing of complex coronary fistulae may be instrumental before interventions or surgery in treatment planning to improve sizing or designing of patient-specific devices. It may be helpful for intraoperative orientation, have educational value, and may be used in communication of the pathology with the affected patient (1).
FIGURE 1 Multimodal Illustration of the Coronary-Venous Fistula

(A) Catheter angiography. (B) Computed tomography (CT) 3-dimensional (3D) volume rendering of fistula. (C) CT 3D volume rendering of additional feeders. (D) 3D print using a binder-jetting technique, part of the left atrium (LA), a block of the ascending—as well as the left atrial appendage—were omitted. Segmentation of the CT data and creation of the model was performed on Mimics Innovation Suite (Materialise, Leuven, Belgium). Cx = circumflex coronary artery; LAD = left anterior descending coronary artery; PA = pulmonary artery; RA = right atrium; RCA = right coronary artery; SVC = superior vena cava.

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KEY WORDS binder-jetting technology, computed tomography, coronary artery fistula, multicolor 3-dimensional printed model

APPENDIX For supplemental videos, please see the online version of this paper.
EDITORIAL COMMENT

The Multidisciplinary Heart Team Approach to Management of Coronary Artery Fistula With the Assistance of 3D Image Reconstruction*

Tabitha G. Moe, MD

In this issue of JACC: Case Reports, Brantner et al. (1) from University Hospital of Basel in Switzerland described a wonderful case of a large, complex coronary venous fistula with additional feeders from the descending aorta. Three-dimensional (3D) printing allowed precise anatomic visualization of the origin, course and drainage site of the fistula. This case wonderfully illustrates the value of imaging in complex coronary artery fistulas.

Coronary artery fistula, also known as a coronary artery venous malformation, is an abnormal communication between a coronary artery and another cardiovascular structure, which may include a cardiac chamber (otherwise referred to as a cameral fistula), coronary sinus, superior vena cava, or pulmonary artery occurring in absence of the myocardial capillary bed. The incidence of coronary artery fistula is 0.1% to 0.2% (2) in all patients undergoing coronary angiography, and most commonly occurs without other associated congenital anomalies. Fistulous communications may be congenital or acquired and can be identified at any age or stage of life. The unique location and physiology of coronary arteriovenous fistula lends to the use of burgeoning 3D imaging technologies in conjunction with a highly integrated heart team for management.

The origin of the fistula may drain from a main coronary artery and is usually a dilated and tortuous artery terminating in one of the cardiac chambers or a vessel. The more proximal the origin from the main coronary artery, the more dilated it is. If the fistula drains to the right atrium with a proximally arising feeding artery, it tends to be considerably dilated but less tortuous. If there is a more distal origin, as when the fistulas originate from the left coronary artery and drain to the left ventricle, they may be very tortuous, presenting a challenge for catheter closure. However, in the less frequently encountered right coronary artery to coronary sinus, the fistula vessel may be large and very tortuous. There may be multiple feeding arteries to a single coronary arterial fistula drainage point or there may be multiple drainage sites.

Fistulas originate from the right coronary artery in 52% of cases, the left anterior descending is the next most frequently involved in approximately 30% of cases, and the LCX in about 18% of cases. Over 90% of the fistulas regardless of origin egress to the right side of the heart, and the remainder drain to the left side of the heart. In the right heart, drainage occurs most frequently to the right ventricle (in about 40%), followed by the right atrium, coronary sinus, and pulmonary trunk. In adults, occasionally fistulas may be encountered that originate from both coronary arteries and drain into the pulmonary trunk.

When the fistula drains to the right side of the heart, there is right-sided volume loading as well as to the pulmonary vascular bed, the left atrium, and the left ventricle. However, when the fistula drains into the left heart, although there is left-sided volume...
loading, there is no increase in the pulmonary blood flow, thus resulting in different echocardiographic appearances. The size of the shunt is determined by the size of the fistula and by the pressure difference between the coronary artery and the chamber into which the fistula drains. Occasionally, congestive heart failure occurs, and rarely, in adults, myocardial ischemia may be seen.

Coronary arterial fistulas are usually asymptomatic in the first 2 decades of life, particularly when they are small, and may even close spontaneously. Complications include “steal” from the adjacent myocardium causing myocardial ischemia, thrombosis and embolism, heart failure, atrial fibrillation, rupture, endocarditis/endarteritis, and arrhythmias. Thrombosis within the fistula is rare, but may cause acute myocardial infarction and atrial and ventricular arrhythmias. The largest shunts occur when a proximal coronary artery connects to the right side of the heart rather than the left heart chambers.

The majority of the patients are asymptomatic. In the older patients, symptoms may include dyspnea on exertion or arrhythmias. Patients with large left-to-right shunts may develop congestive heart failure. If angina is documented, it may be due to coronary artery steal; pulmonary hypertension secondary to long-term high-volume R-L shunts can also be seen.

Specific management strategies, which can include surgical repair or catheter embolization, are somewhat controversial. In the largest recorded series of 46 patients treated with surgery, pre-operative symptoms included angina and HF (3). Importantly, post-operative myocardial infarction occurred in 11% because of low flow in the dilated coronary artery proximal to fistula closure. An interventional approach is best evaluated by a multidisciplinary team including cardiothoracic surgery, interventional cardiology, structural cardiology, and advanced imaging.

Most patients are referred because of a continuous murmur, loudest over the precordium, which may be thought to be due to patent arterial ductus. However, the murmur is heard over the mid-chest, or even lower, rather than below the left clavicle and typically peaks in mid to late diastole rather than systole. If the fistula connects to the left ventricle, only an early diastolic murmur may be heard. Some patients with large shunts may present with signs of congestive cardiac failure and angina, usually at the extremes of life.

Two-dimensional and color Doppler echocardiography are helpful in demonstrating dilation of the affected coronary artery and on color flow mapping may show the site of drainage, but it is difficult to define the detailed anatomy of the fistula with echo. Cardiac magnetic resonance imaging may be helpful in confirming the diagnosis, as the proximal coronary arteries or even the whole length of the fistula vessel may be seen. Fractional flow reserve cardiac computed tomography angiography and 3D volumetric rendering of cardiac computed tomography angiography are valuable in procedural planning.

Procedural options can be optimized by careful identification of the number of fistulous connections, nature of the feeding vessel or vessels, sites of drainage, and quantification of myocardium at risk. The goal of treatment is the occlusion of the fistula, while maintaining normal myocardial perfusion. The indications for treatment of CAVF include the presence of a large or increasing left-to-right shunt, left ventricular volume overload, myocardial ischemia, left ventricular dysfunction, or congestive cardiac failure, and for prevention of endocarditis/endarteritis.

The treatment options for CAVF include surgery or catheter closure. Surgery involves internal closure of the fistula within the receiving chamber or vessel whenever feasible, but when the fistula is associated with a large aneurysm of the feeding artery, it may need to be ligated from within the aneurysm. Surgery is associated with a low morbidity and mortality rate; infarction may occur in <5% of cases and there is a risk of recurrence. The reason for the recurrence includes the fact that there may be multiple fistulas present that are difficult to visualize intraoperatively, advocating for a hybrid approach.

Catheter closure of the fistulas is an effective and safe alternative to surgery. The aim of catheter closure is to occlude the fistula artery as distally and as close to its termination point as possible, so as to avoid any possibility of occluding branches to the normal myocardium. Whichever technique of catheter closure is used, the occlusion should be at a precise point. In some patients, it may be easier to enter the fistula from the right side of the heart. These may be suitable for occlusion with Amplatzer occluder devices (Abbott, Abbott Park, Illinois), such as vascular plug, duct occluder, or atrial or ventricular septal occluder.

After occluding the main fistulous vessel, repeat selective coronary angiography in both coronary arteries is essential, as a second branch feeding the fistula or multiple feeding vessels may be visualized. With catheter-based closure techniques, complete occlusion of the fistula may be achieved in >95% of the patients. In the remaining patients, either further procedures may be required to close the fistulas or
they may be managed conservatively if the residual fistulas are small. All complications are rare and include premature deflation of a detachable balloon, inadvertent coil embolization, transient T-wave changes, transient bundle branch block, and myocardial infarction.

3D imaging and printing now allow for manipulation of the aneurysm both in a virtual environment as well as in vivo simulation to determine the most efficient method to address the fistulae. This potentially reduces fluoroscopy time as well as radiation dose and decreases the likelihood of device failure or migration should device placement be considered. The management of the fistula clinically is more important at the egress than the origin. There are a variety of approaches that may be appropriate and should all be considered in addressing fistula closure. Strategies including coil embolization, vascular plugs, and septal occluder devices can all be electronically modeled and implanted in a virtual environment as well as trial therapy in a 3D printed environment. The collaborative environment for management of late-presenting symptomatic coronary fistulae includes the multidisciplinary heart team approach. The presence of coronary artery fistula requires review by a knowledgeable heart team that may include congenital and noncongenital cardiologists and surgeons to determine the role of percutaneous and/or surgical closure.

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KEY WORDS 3-dimensional printing, computed tomography, coronary angiography, coronary vessel anomaly, imaging
Alternating bundle branch block pattern on electrocardiogram (ECG) is a concerning finding with important prognostic implications. This ECG challenge explores the electrophysiological mechanism of a case of alternating bundle branch block with alternating PR intervals. *(Level of Difficulty: Beginner.)* *(J Am Coll Cardiol Case Rep 2020;2:1742–4)* © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license *(http://creativecommons.org/licenses/by-nc-nd/4.0/).*

A 83-year-old man, whose baseline electrocardiogram (ECG) had a right bundle-branch block (RBBB) and left posterior fascicular block (LPFB), and who underwent transcatheter aortic valve replacement (TAVR) with a balloon-expandable valve 4 weeks before, was admitted to the hospital for symptomatic anemia. A 12-lead rhythm strip was reconstructed from telemetry *(Figure 1A).*

What is the mechanism of alternating bundle branch block?

1. Intermittent phase 3 block in the bundle branches
2. Intermittent phase 4 block in the bundle branches
3. Variable conduction delay in both bundle branches
4. Premature ventricular contractions with isorhythmic atrioventricular (AV) dissociation

**DISCUSSION**

The best explanation for this patient’s ECG is variable conduction delay in both bundle branches. Bundle-branch block (BBB) patterns on ECG are typically caused by relative conduction delay in the left bundle (LB) or the right bundle (RB) rather than complete conduction block. Furthermore, conduction delay does not need to be fixed and can occur intermittently.

Before TAVR, the patient’s ECG showed sinus rhythm at a rate of 70 beats/min, with normal PR interval (170 ms), right-axis deviation (QRS axis 97°), RBBB (QRS duration 128 ms), and LPFB *(Supplemental Figure 1).* The RBBB and LPFB indicate that the left anterior fascicle (LAF) was the faster conducting fascicle. The patient likely had intermittent conduction in the RB, but at a slower conduction velocity than the LAF, producing a RBBB and LPFB pattern on the ECG. Following TAVR, the patient’s ECG showed sinus bradycardia at a rate of
54 beats/min, normal axis (QRS axis 64°), first-degree AV delay (PR interval 238 ms), and RBBB (QRS duration 128 ms) (Supplemental Figure 2). He had developed PR prolongation, and the pre-existing LPFB was no longer evident, likely because of balanced delay in the LAF, induced by mechanical injury.

On the reconstructed rhythm strip (Figure 1A), with sinus tachycardia (rate: 102 beats/min), the patient had primarily RBBB (QRS duration: 130 ms) with a normal PR interval (180 ms). When the RB is able to intermittently conduct, it now conducts faster than the LAF, resulting in a shorter PR interval than baseline (140 ms) and left bundle-branch block (LBBB) QRS duration 150 ms. Figure 1B provides a schematic diagram of the patient’s conduction system and our proposed mechanism for his ECG. The fixed sinus rate without variability and absence of atrial ectopy argues against phase 3 block and phase 4 block, respectively. The relatively fixed PR interval associated with the LBBB-morphology QRS complexes argues against a ventricular origin.

Thus, the patient was diagnosed with alternating BBB due to variable conduction delay in both bundle branches. In 1964, Lepeschkin described alternating bundle

**FIGURE 1** Electrocardiogram

(A) Reconstructed 12-lead rhythm strip electrocardiogram. (B) Schematic diagram.
branch block and its tendency to progress to advanced heart block (1). In 2010, Massumi published a series of 16 patients with alternating BBBs and PR intervals, who all subsequently developed high-grade AV block requiring pacemaker placement (2). Most recently, in 2017, van Gils et al. found that, among patients with pre-existing RBBB who underwent TAVR, 8% developed alternating BBB within 24 h (3). Given the development of alternating BBB post TAVR, and the significant risk of progression to high-grade heart block, the patient ultimately underwent uncomplicated placement of a permanent pacemaker.

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KEY WORDS aortic valve, electrocardiogram, valve replacement

APPENDIX For supplemental figures, please see the online version of this paper.
The Hidden Meaning Behind Alternating Bundle Branch Block

Sofian Johar, MBChB, PhD,a,b,c Eric Lim, MB BChRd

Transcatheter aortic valve replacement (TAVR) is an established treatment for severe aortic stenosis. An important peri-procedural complication of TAVR is new onset atrioventricular conduction disturbance (1) which occurs in 10.5% to 28.2% of patients in the early post-operative period. This complication results from close proximity of the aortic valve to the His-Purkinje system, particularly when the this system is relatively left-sided or courses under the membranous septum, as occurs in 30% and 20% of individuals, respectively (2). We now know that a large variety of complex atrioventricular conduction disturbances can occur post-TAVR.

In this issue of JACC: Case Reports, Kulkarni et al. (3) present a case of alternating bundle branch block (BBB) following TAVR.

The initial rhythm before TAVR is sinus with bifascicular block consisting of right bundle branch block (RBBB) and left posterior fascicular block, the latter evidenced by right-axis deviation, an rS pattern in lead I, and qR in leads III and aVF. The PR interval is normal at 170 ms. Following TAVR, the electrocardiogram shows loss of right-axis deviation and prolongation of the PR interval to 238 ms. Although it is possible that TAVR led to immediate reversal of the conduction disturbance in the left posterior fascicle, a much more likely explanation is that TAVR instead led to damage of the left anterior fascicle, thereby causing balanced delay in left-sided fascicles and normalization of the QRS conduction axis. This nicely accounts for concomitant prolongation of the PR interval.

A corollary to this explanation is that despite the sole appearance of RBBB following TAVR, there must also be a severe but inapparent delay in the left bundle branch (LBB). From observations such as this, together with invasive measurements in the electrophysiology laboratory, electrophysiologists now realize that RBBB and left bundle branch block (LBBB) often reflect delays in the bundle branches rather than actual, absolute conduction block (4–6). Such delays lead to so-called masking of disease in the contralateral bundle branch.

Tzogias et al. (6) have demonstrated this phenomenon elegantly in 50 patients with baseline LBBB who underwent right-sided heart catheterization and developed RBBB (rather than complete heart block) resulting from mechanical trauma to the RBB. This can plausibly be explained only by delayed conduction (instead of block) within the LBB. Furthermore, Tzogias et al. (6) teach us that an electrocardiographic pattern of RBBB but with an absent S-wave in leads I and aVL suggests concomitant LBB delay and enables a diagnosis of bilateral bundle branch delay. This is because the S-wave in leads I and aVL represents delayed right ventricular depolarization in RBBB, which can be normalized by concomitant LBB delay. If an S-wave is present, then this may signify isolated RBBB or bifascicular block. Interestingly and perhaps unexpectedly, in the present case we do see a small S-wave in leads I and aVL, which we hypothesize may be caused by unequal delay in the left anterior and posterior fascicles and/or insufficient relative delay in left ventricular depolarization to mask the S-wave. In
Alternating Bundle Branch Block

the series reported by Tzogias et al. (6), the S-wave in leads I and aVL was observed for both isolated left anterior and isolated left posterior fascicular block with concomitant catheter-induced RBBB. Correspondingly, loss of the S-wave was shown to be a highly specific sign (100%) of masked LBB delay, but it seems only moderately sensitive (64%).

To clinch their hypothesis of bilateral bundle branch delay, Kulkarni et al. (3) present a telemetry strip showing alternation of QRS configurations consistent with LBBB and RBBB. A key observation is that each QRS configuration is tightly wedded to a specific PR interval. There is minimal change in the PP interval, making acceleration- and deceleration-dependent (phase III and phase IV) blocks unlikely. Instead, intermittent RBB conduction leads to alternating masking and unmasking of LBB delay. This seems to be the only reasonable explanation linking the PR interval with the QRS configuration.

This type of masking of 1 bundle branch block by the other has long been recognized. As far back as 1954, Richman and Wolff described LBBB “masquerading” as RBBB (7). This is most often seen as the coexistence of an RBBB pattern in the precordial leads but an LBBB pattern in the limb leads with absent S waves in leads I and aVL. The LBBB pattern in the limb leads with absent S waves in leads I and aVL is reminiscent of, and recapitulates the findings of, Tzogias et al. (6), as described earlier. Other reported variations of masking include left anterior hemiblock concealing RBBB (8). To our knowledge, a specific case of LBBB masking RBBB has not been reported, but the case presented here (3) could be regarded as such an example, albeit occurring intermittently.

What are the practical implications of these complex atrioventricular conduction disturbances following TAVR? To date, management of conduction disturbances post-TAVR varies widely among centers. For this reason, last year, a JACC Scientific Expert Panel reviewed the available evidence and published management recommendations (9). In this report, alternating bundle branch block does not appear as part of the definition of high-grade atrioventricular block, but as we convincingly see here, such a finding can only signify severe bilateral bundle branch disease. Although this may be transient following TAVR, we urge caution if such patients are managed without a pacemaker. As pointed out by Kulkarni et al. (3), Massumi et al. (10) published a series of 16 patients with alternating PR intervals and BBB who all developed high-grade atrioventricular block subsequently and needed pacemaker implantation. For practical purposes, the pattern of alternating BBB should be treated as equivalent to high-grade atrioventricular block or complete heart block.

We additionally note that the presence of pre-existing RBBB is already an important electrocardiographic feature identifying patients at risk for pacemaker implantation post-TAVR. However, for the reasons explained earlier, we can hypothesize that patients with pre-existing RBBB who also have absent S waves in leads I and aVL may be at even higher risk. This would be an important subject for further study.

In recent years, so-called physiological pacing using His bundle (HB) and LBB-area pacing systems has become increasingly prevalent. Success rates are lower in patients with atrioventricular conduction block, but early evidence suggests that implantation of such pacing systems is feasible post-TAVR (11,12). Presumably because the site of the block is at or near the HB, such pacing seems able to overcome the diseased conduction tissue in the HB that is predestined to become the LBB (13) (so-called longitudinal dissociation). Nevertheless, in the largest study to date (12), HB pacing was successful in only 63%. In many such patients, pacing more distally at the area of the LBB did permit correction of BBB (in 93% of patients who underwent an attempt at BBB correction). It is unknown whether there are electrocardiographic features predicting failure of HB pacing to overcome BBB. This case report would suggest that HB pacing is less likely to succeed if there are alternating PR intervals with alternating BBB. Possibly, RBBB with loss of the S-wave in leads I and aVL may also serve as a similar electrocardiographic warning. In such cases, adoption of LBB-area pacing may be preferred.

In conclusion, Kulkarni et al. (3) present an interesting case showing alternating PR intervals and BBB in a post-TAVR patient. Such an electrocardiographic appearance suggests significant disease in the bilateral bundle branches meriting treatment as for high-grade atrioventricular block. This case also serves as a reminder that BBB may not really be block and that so-called block may often really be hidden bundle branch conduction delay.

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KEY WORDS aortic valve, bradycardia, cardiac pacemaker
Vagal activation usually affects both the sinus and atrioventricular (AV) nodes, manifesting as sinus slowing accompanied by varying degrees of AV block. AV block accompanying sinus acceleration as during treadmill testing is usually considered pathologic. We report 2 cases of vagally mediated reflex AV block accompanied by sinus tachycardia and acceleration.

(Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1748–52) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Vagal activation is known to simultaneously affect both the sinus and atrioventricular (AV) nodes. The resulting electrocardiographic (ECG) manifestations can include sinus rate slowing, sinus arrest, and varying degrees of AV node block. One of the characteristic ECG hallmarks of vagally mediated bradycardia is the simultaneous occurrence of AV block accompanied by sinus slowing. Therefore, when sinus slowing and AV block occur simultaneously, it is correctly interpreted as reflex in origin and therefore benign. On the other hand, it is often taught that AV block that occurs during sinus acceleration (such as during treadmill exercise testing) should be assumed to be pathologic until proven otherwise, and often leads to consideration of pacemaker implantation.

It may be underappreciated that vagal activation may have disparate effects on the sinus and AV nodes, or may be accompanied by sympathetic co-activation. We report 2 instances of clear vagally mediated AV block, but with concurrent sinus acceleration.

CASE 1

A 46-year-old woman with past medical history of irritable bowel syndrome, obstructive sleep apnea, and moderate obesity presented for upper gastrointestinal endoscopy for gastric polyp removal. Coincident with stomach and duodenal insufflation, she developed a 7-s period of ventricular asystole due to...
AV block. During this period of vagally mediated AV block, her sinus rate was rapid, and accelerated to approximately 120 beats/min (Figure 1). With termination of insufflation, normal AV conduction resumed, and her heart rate shortly returned to 75 beats/min. Propofol was discontinued, the procedure was aborted, and she awoke without complications. She had no history of syncope or presyncope. Her physical examination, resting ECG, and echocardiogram were normal. She was discharged with instructions to obtain a sleep study as an outpatient, and to seek immediate medical attention for presyncope or syncope. She has not reported any symptoms since February 2019.

CASE 2

A 61-year-old athletic woman with a structurally normal heart and a normal resting ECG had 2 episodes of syncope with minimal prodrome. Outpatient monitoring revealed rare PVCs that were “short coupled.” She underwent an electrophysiology study without inducible arrhythmias. An implantable loop recorder was inserted. Outpatient monitoring 14 months after loop implantation identified an 8-s period of asystole (Figure 2) that occurred during an episode of nausea, diaphoresis, retching followed by vomiting and extreme lightheadedness without syncope, typical of a vagal event. Her sinus rate initially remained at approximately 100 beats/min although she developed a prolonged pause punctuated by occasional QRS complexes from an unreliable escape rhythm. Later during the episode, excessive artifact obscures accurate assessment of P waves, but there may have been some sinus rate slowing as the bradycardia progressed.

DISCUSSION

In general, AV block that develops during sinus tachycardia or during sinus acceleration should be...
considered to be pathologic until proven otherwise. On the other hand, AV block that is preceded or accompanied by sinus slowing is most likely to be reflex in origin, mediated by vagal effects on both the sinus and AV node. Such reflex bradycardia (sinus slowing along with the development of AV block) is commonly seen during a variety of abdominal procedures and extensively described in the literature. We report 2 cases of vagally mediated heart block during rapid sinus rates.

In the midst of nausea, extreme diaphoresis, retching, and presyncope (all consistent with a vagally mediated syndrome), the sinus rate (indicated by red arrows) remains at approximately 100 beats/min although atrioventricular (AV) node block occurs culminating in significant ventricular asystole. Excessive artifact toward the end of the recording does not allow accurate assessment of sinus cycle length.
The first case is unusual in that vagal activation during colonic insufflation resulted in AV block during on-going sinus tachycardia without sinus slowing; in fact, the sinus node accelerated, seemingly a “disconnect” between vagal influence on the 2 nodes. The second case showed continued sinus rates of 95 to 100 beats/min for the first many seconds of vagal AV block, although P waves were difficult to assess because of excessive artifact. It is known that sinus node automaticity is more powerfully influenced by vagal inhibition, whereas AV node conduction is largely controlled by sympathetic activation. Therefore, one often sees sinus slowing with continued AV conduction or sinus arrest during vagal activation, but our 2 cases showed the reverse responses. However, it must be acknowledged that vagal activation rarely occurs in isolation, and most often there is an on-going balance between sympathetic and vagal tone. The gastrointestinal tract is a known source of vagal afferents, and deglutition syncope, especially with cold substances, is a well-described clinical entity. We reviewed 15 published reports of this condition where ECGs during deglutition were available, and none of the ECGs showed sinus acceleration during heart block. Similarly, colonic insufflation during lower endoscopy is also known to cause vagal activation has been reported to occur in 16% of patients (1), resulting in bradycardia due to sinus slowing and/or AV block (2).

The mammalian heart is innervated by post-ganglionic vagal fibers with significant overlap in innervation of both the sinus and AV nodes (3). Typically, vagal stimulation results in sinus node slowing accompanied by slowing of conduction though the AV node. Data describing asymmetry of sympathetic innervation of the heart have been published in the rat model (4). There have been several animal studies exploring the differing effects of the right and left vagal nerves on the activity of the sinus and AV nodes. Stauss (5) studied the effect of left- and right-sided vagal nerve stimulation on the hemodynamics of hypertensive rats. Cervical vagal nerve stimulation was applied at differing strengths and frequencies, and for different durations; they found that left-sided vagus nerve stimulation produced more pronounced bradycardia than right-sided stimulation. Similarly, Schiereck et al. (6) concluded that left vagal stimulation introduced more heart rate irregularities than right vagus in their study of asynchronous vagal stimulation of rats.

In human volunteers, right carotid baroreflex activation resulted in greater sinus slowing as compared to left-sided activation (7). Furthermore, data confirm that there can be simultaneous activation of the sympathetic and the parasympathetic systems, at least in animal experiments. There have been 2 prior case reports of divergent sinus and AV node responses during vasovagal syncope induced by head-up tilt table testing when sinus tachycardia and AV block coexisted (8,9). Differences in sinus and AV nodal autonomic modulation have also been documented based on the differential behavior of sinus rates and PR intervals during sleep (10).

CONCLUSIONS

These 2 cases highlight paradoxical increase of sinus rate or lack of sinus slowing during vagally mediated AV block. Although uncommon, such divergent behavior highlights differing effects of vagal activation on the sinus and AV nodes, or possibly co-activation of sympathetic and parasympathetic systems. These cases negate the conventional clinical teaching that AV block during sinus tachycardia is always pathologic and an indication for pacemaker implantation. Although usually true, reflex AV block in the setting of sinus acceleration is not always pathologic.

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KEY WORDS autonomic function, electrocardiography, heart block, vagal activation
MINI-FOCUS ISSUE: ARRHYTHMIAS AND EP

CASE REPORT: CLINICAL CASE

Inadvertent Disabling of Implantable Cardiac Defibrillator Antitachycardia Therapies Following Breast Reconstructive Surgery

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ABSTRACT

A 47-year-old woman with an implantable cardiac defibrillator and breast cancer underwent left breast mastectomy with simultaneous reconstruction using a breast tissue expander. She was found to have intermittent disabling of tachyarrhythmia detection and therapy functions of her implantable cardiac defibrillator that were triggered by the breast tissue expander magnetic port. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1753–6) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 47-year-old woman presented with complaints of a sporadic, high-pitched beeping sound and a vibration sensation coming from her chest for 1-day duration. Two days before her presentation she had undergone a left breast mastectomy with immediate reconstruction using a Mentor Aurora breast tissue expander (Johnson and Johnson, New Brunswick, New Jersey) for grade 1 invasive lobular breast carcinoma. A magnet was used during the operation, and postoperative implantable cardiac defibrillator (ICD) interrogation demonstrated normal function. The operation was without immediate complication and she was discharged home the following day. Two days after discharge, the patient began to hear an intermittent high-pitched beeping sound. After turning off all of the electronics in the house, she soon realized that the sound and simultaneous vibration was originating from her chest. This was particularly notable whenever she leaned forward or raised her left arm. She denied any other signs or symptoms, and never experienced a syncopal episode or defibrillator shock.

The patient presented to the emergency department where vitals were noted to be within normal limits and physical examination was unremarkable with the exception of a well-healing surgical wound.

LEARNING OBJECTIVES

- To raise awareness of this potentially life-threatening interaction between magnetic components of breast tissue expanders (or other chest prostheses) and ICD function.
- To promote prompt recognition and rectification if this situation is encountered post-operatively.
- To understand that, if faced with this situation pre-operatively, clinicians should recommend use of alternative prostheses that do not have magnetic components.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors’ institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the JACC: Case Reports author instructions page.

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The patient had a history of spontaneous sustained monomorphic ventricular tachycardia with implantation of a single lead Medtronic implantable cardioverter-defibrillator (Model: Visia AF MRI VR DVT SB 1 D4) for secondary prevention approximately 1 year earlier and recently diagnosed grade 1, invasive lobular breast carcinoma with multifocal hormone positivity (estrogen receptor 95%, progesterone receptor 95%, human epidermal growth factor receptor 2/neu negative, Ki67 21%).

**DIFFERENTIAL DIAGNOSIS**

The differential diagnosis of a high-pitched beeping sound and vibration over her ICD included cardiac device malfunction or deactivation from a number of potential mechanisms following left chest surgery.

**INVESTIGATIONS**

The patient presented to our facility where ICD interrogation showed normal function and stable pacing and sensing thresholds. However, after further inquiry it was discovered that the recently implanted breast expander had a magnetic port that intermittently disabled the tachyarrhythmia detection and therapy function of the ICD 23 times over the preceding 2 days. We deduced that when the patient leaned forward or raised her left arm, the magnetic port on the breast tissue expander came into close proximity to the defibrillator, leading to inhibition of tachyarrhythmia detection and therapies. The magnetic port and defibrillator relationship can be seen on the chest radiograph in Figure 1 and the dynamic nature of the magnetic port and defibrillator with motion is depicted in the illustration in Figure 2. We also suspect the magnetic port interaction became particularly prominent in the immediate days following surgery as her post-operative swelling subsided. Fortunately, she did not suffer from any malignant ventricular arrhythmias during these vulnerable periods of ICD deactivation.

**MANAGEMENT**

The patient was admitted and underwent left breast tissue expander exchange involving the removal of the left breast magnetic port containing tissue expander and immediate implantation of a magnetic-free adjustable saline breast implant. Post-operative ICD interrogation showed appropriate device function and she was discharged home the same day.

**DISCUSSION**

Women in the United States have a 1 in 8 (or approximately 13%) lifetime risk of developing breast cancer (1). Advances in adjuvant chemo- and radiotherapy now allow for mastectomy with immediate breast reconstruction in many circumstances. Approximately 275,000 ICDs have been implanted in women in the United States over the past decade (2). The American Society of Plastic Surgeons reported that there were approximately 75,000 breast reconstructions in the United States using tissue expanders/implant in 2014 (3). Recent data suggest that heart disease, particularly heart failure, is an independent risk factor for developing cancer (4). Therefore, many women with an ICD will develop breast cancer and potentially undergo breast surgery. With the growth of cardio-oncology clinics throughout the country, this situation may be increasing faced by the cardiology community.

Reconstructive breast surgery frequently involves the use of breast tissue expanders that contain a magnetic injection port. The magnetic injection port facilitates targeted saline injections for implant expansion, thereby avoiding inadvertent needle puncture of the tissue expander itself. The minimum required field strength of a magnet to induce electromagnetic interference in a cardiac device is >10
In general, most magnets manufactured to deactivate ICDs have a field strength $>90$ Gauss. Breast tissue expander magnetic ports generate a magnetic field ranging from 65 to 175 Gauss (5).

Implantable cardiac devices have various alert features in the form of audible signals and/or vibrations of varying length, tone, and patterns depending on the device manufacture and programming. These alerts are designed to signal if there is a change in the cardiac device, such as improper functioning. The functioning of implantable cardiac devices can be altered with a magnet. Depending on the device and its programming, this can change the mode of application or suspend detection of dysrhythmias, therefore disabling therapies that would otherwise be delivered.

The U.S. Food and Drug Administration (6) published a warning on March 8, 2016, regarding magnetic interference between breast tissue expanders with magnetic ports and cardiac implantable devices. However, it was stated that there was a very small population at risk due to the general infrequency of patients with cardiac devices who also undergo breast reconstruction. Few direct data exist in this situation, and epidemiologic data would suggest otherwise. A literature review revealed only 2 case reports detailing a similar presentation: Agarwal et al. (7) reported a woman with history of ICD placement for hypertrophic cardiomyopathy who later underwent bilateral mastectomy with breast tissue expander implantation. Sher Khan et al. (8) detailed a woman with a history of breast cancer status post mastectomy with breast tissue expanders that later required ICD implantation for chemotherapy-induced cardiomyopathy. Both cases also reported that the women presented with complaints of hearing an abnormal sound and were found to have the magnet of their breast tissue expander interacting with their ICD, temporarily suspending all antitachycardia therapies.

**FOLLOW-UP**

The patient presented for follow-up without any further complaints of abnormal sounds originating from her device. The device has not experienced any unexpected disabling of tachyarrhythmia detection or therapy function.

**CONCLUSIONS**

This case highlights the rare and potentially life-threatening interaction between a chest prosthetic device involving a magnetic field with an ICD. Prosthetic material without magnet components should
be preferentially used in this select patient population.

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**KEY WORDS** breast cancer, breast tissue expander, cardio-oncology, implantable cardiac defibrillator
CASE REPORT: CLINICAL CASE

Cardiac Transplantation for Refractory Catecholaminergic Polymorphic Ventricular Tachycardia

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ABSTRACT

We present a patient with catecholaminergic polymorphic ventricular tachycardia who failed maximal antiarrhythmic drug therapy and bilateral sympathetic denervation, who presented with syncope and recurrent ventricular tachycardia for 11 min refractory to 21 shocks. She underwent cardiac transplantation as curative treatment for refractory ventricular arrhythmias in catecholaminergic polymorphic ventricular tachycardia. (Level of Difficulty: Advanced.)

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A 27-year-old woman with catecholaminergic polymorphic ventricular tachycardia (CPVT) presented in 2019 following syncope. She described sudden-onset dizziness while walking and then received several implantable cardioverter defibrillator (ICD) shocks resulting in loss of consciousness. She awoke denying chest pain, shortness of breath, palpitations, weakness, or incontinence before the event. On hospital arrival, she noted only chest soreness. She denied recent illness, decreased oral intake, stress, or recent changes in medication, which included propranolol LA 60 mg daily, verapamil 120 mg daily, and flecainide 150 mg twice daily.

Vital signs were blood pressure 111/68 mm Hg, heart rate 60 beats/min, and respiratory rate of 16 breaths/min saturating 98% on room air. Her physical examination was unremarkable, including regular cardiac rate and rhythm, no cardiac murmur, clear lungs bilaterally, soft abdomen, and no significant lower extremity edema. Laboratory data showed potassium 3.0 mmol/l, magnesium 1.8 mmol/l, troponin 12.34 ng/ml, creatine kinase 1,192 U/l, brain natriuretic peptide 15 pg/ml, thyroid stimulating hormone 0.97 μIU/ml, and flecainide level of 0.43 μg/ml.

Propranolol LA was increased to 120 mg daily and her electrolytes were repleted. Transthoracic echocardiogram showed preserved left ventricular ejection fraction with no regional wall motion abnormalities. ICD interrogation revealed persistent

LEARNING OBJECTIVES

- Review initial CPVT medical management.
- Discuss advanced medical therapy and surgical options for management of CPVT.
- Suggest consideration of cardiac transplantation as a final approach for severe, refractory cases of CPVT.

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors’ institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the JACC: Case Reports author instructions page.

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ventricular tachycardia (VT)/ventricular fibrillation (VF) refractory to multiple ICD shocks over 11 min. Given persistent, refractory ventricular arrhythmias in a patient with CPVT as described as follows, cardiac transplantation evaluation was initiated.

**PAST MEDICAL HISTORY**

The patient was diagnosed with ryanodine receptor mutation CPVT at the Gly2295 amino acid as a child after her mother died from the condition at 22. For years, the patient was asymptomatic, ultimately requiring medical management following episodic VT. The arrhythmia was well controlled for several subsequent years before she suffered a syncopal episode leading to placement of a St. Jude Medical dual-coil Ellipse DR 2411-36C ICD device in 2010.

Three years before the index admission, the patient’s course worsened, with several episodes of recurrent VT. Despite compliance with ultimately 3 drugs (nadolol, verapamil, and flecainide), she experienced recurrent syncope. After bilateral thoracoscopic sympathectomy in 2018, the patient reported significant improvement in palpitations, and she did very well clinically overall. Device interrogations in the interim showed rare atrial arrhythmias and no therapies delivered due to recurrence of VT on her medication regimen of propranolol, verapamil, and flecainide. Attempts at down titration of verapamil and propranolol were unsuccessful because of profound increase in palpitations.

**DIFFERENTIAL DIAGNOSIS**

Given known history of CPVT, the differential diagnosis for this presentation started with refractory CPVT due to exercise or subtherapeutic medication levels. Other potential explanations included medication or drug toxicity or noncompliance, hyperthyroidism, and electrolyte abnormalities. The multidisciplinary team felt that given the refractory nature of this patient’s CPVT, this presentation was likely a breakthrough VT episode without exercise despite maximal medical therapy.

**INVESTIGATIONS**

Flecainide level was therapeutic. Urine drug screen was negative. Initial electrocardiogram showed an atrial-paced rhythm, otherwise unremarkable. Chest radiograph and computed tomography did not show any acute processes, noting a left-sided ICD generator with leads in the right atrial appendage and ventricular apex.

ICD interrogation showed the device functioning normally with appropriate settings (Table 1). Review of events revealed 11 recurrent episodes of VT or VF over 11.5 min, with the last episode persisting for nearly 4 min (Table 2). The ventricular arrhythmias were refractory to a total of 14 antitachycardia pacing (ATP) episodes and 21 ICD discharges. In the final event, VF persisted despite maximal ICD discharge capacity, with interrogation noting “No More Therapies” (Figure 1). VF continued for 53 s after the last ICD shock before spontaneously converting to normal sinus rhythm (Figure 2).

**MANAGEMENT**

The patient was continued on propranolol, verapamil, and flecainide during her admission. The patient experienced occasional, mild dizziness with ambulation but remained hemodynamically stable, and no arrhythmias were noted on telemetry. She was listed for cardiac transplantation as United Network for Organ Sharing Status 2.

After 10 days, cardiac transplantation was performed. Pre-operative transesophageal echocardiogram showed normal left ventricular ejection fraction, prominent left ventricular hypertrophy, and no significant valvular dysfunction. The surgery and post-operative course were uncomplicated.

### TABLE 1 ICD Settings on Presentation

| Device Test Results | Capture | Sense | Lead Impedance |
|---------------------|---------|-------|----------------|
| A 1.0 V @ 0.5 ms    | 2.1 mV  | 380 Ω |
| V 1.625 V @ 1.0 ms  | 4.2 mV  | 310 Ω |
| HV                  | 40 Ω    |       |

| Device Parameters |
|-------------------|
| Mode              | DDDR    |
| Base Rate         | 60 beats/min |
| Max Track Rate    | 125 beats/min |

| Zone Configuration | VT-1 | VT-2 | VF |
|--------------------|------|------|----|
| Detection criteria | 144 beats/min | 181 beats/min | 214 beats/min |
| Therapy (enabled)  | ATP x4 | ATP x1 |
|                   | ATP x4 | B800 V |
|                   | 875 V x2 | 875 V x4 |

ATP = antitachycardia pacing; DDDR = dual-chamber, rate-modulated; ICD = implantable cardioverter defibrillator; VF = ventricular fibrillation; VT = ventricular tachycardia.
CPVT is a rare type of polymorphic VT that occurs in the absence of structural heart disease or associated syndromes. Most CPVT cases are associated with gene mutations in ryanodine receptor or calsequestrin 2, either of which increases calcium release from the cardiomyocyte sarcoplasmic reticulum during diastole, resulting in intracellular calcium overload and delayed after-depolarizations and triggered activity (1,2).

The clinical presentation of CPVT varies from asymptomatic (genetic diagnosis) to pre-syncope, syncope, or cardiac arrest secondary to VT or VF, often triggered by stress (3). Diagnostic testing for CPVT is challenging given the transient and sometimes fatal nature of the arrhythmia. If an episode of CPVT is captured on electrocardiogram, the typical finding is polymorphic VT with beat-to-beat QRS morphology variation or bidirectional tachycardia (4).

Patients with CPVT should be instructed to limit stress and avoid strenuous sporting (Class I). Patients who are symptomatic (Class I), asymptomatic (Class IIa), or carriers of pathogenic mutations (Class IIa) should be started on nonselective beta-blocker therapy; nadolol is preferred (5,6). Even with beta-blocker therapy, an ICD may be required. The rate of breakthrough arrhythmias on beta-blocker therapy ranges from 3% to 11% annually (7). Therefore, patients should be assessed for recurrent ventricular arrhythmias even after initiation of beta-blocker therapy.

CPVT is often well controlled through single- or dual-agent medical management, with ICD placement as indicated. Breakthrough episodes of VT/VF generally respond to up titration of baseline medications and, if necessary, addition of a third medication. Cases not amenable to multimodal medical management are typically referred for bilateral thoracoscopic cardiac sympathectomy. In this unusual refractory case, cardiac transplantation was the only remaining therapy. To our knowledge, this is the first case of cardiac transplantation as curative treatment for refractory CPVT.

FOLLOW-UP
The patient has had no further evidence of arrhythmia since cardiac transplantation.

CONCLUSIONS
CPVT is often well controlled through single- or dual-agent medical management, with ICD placement as indicated. Breakthrough episodes of VT/VF generally respond to up titration of baseline medications and, if necessary, addition of a third medication. Cases not amenable to multimodal medical management are typically referred for bilateral thoracoscopic cardiac sympathectomy. In this unusual refractory case, cardiac transplantation was the only remaining therapy. To our knowledge, this is the first case of cardiac transplantation as curative treatment for refractory CPVT.

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FIGURE 1 Ventricular Fibrillation Refractory to Maximal ICD Discharges

This figure shows the implantable cardioverter defibrillator (ICD) interrogation from this patient showing persistent ventricular tachycardia refractory to defibrillation. Ultimately, 93 s after onset of the patient’s final episode of ventricular fibrillation (VF), the ICD exhausted all therapies. AS = atrial sensing; F = fibrillation; HV = high-voltage therapy; VS = ventricular sensing.
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KEY WORDS cardiac transplantation, ventricular fibrillation, ventricular tachycardia
Direct Current Ablation of Deep Substrate Arrhythmia

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ABSTRACT
Direct-current ablation has been reinvestigated in animal models with considerably good outcomes and safety margins. Its modified version using biphasic energy lowers the current density further, minimizing its complications. We report a first-in-human ablation of ventricular tachycardia using biphasic direct current with short-term success and no procedural complications. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1762–5)

HISTORY OF PRESENTATION
A 61-year-old male was admitted for recurrent ventricular tachycardia (VT). The patient had a medical history of nonischemic cardiomyopathy status post-biventricular cardioverter-defibrillator implantation and VT, which was refractory to multiple antiarrhythmic drug therapy, and 4 prior attempts at radiofrequency (RF) ablation and cardiac sympathetic denervation. He had undergone his last RF ablation 8 months earlier and cardiac sympathetic denervation 3 months previously. The patient was taking the maximum doses of mexiletine and metoprolol.

DIFFERENTIAL DIAGNOSIS
Diagnosis was consistent with recurrent VT based on an arrhythmia log from his implanted cardioverter-defibrillator.

INVESTIGATION
He underwent an electrophysiology study, results of which were consistent with clinical VT.

MANAGEMENT
With the refractory VT, the patient underwent an unconventional procedure: electroporation or direct-current (DC) ablation. The 3-dimensional (3D) electroanatomical mapping showed deep septal focus correlating with his clinical VT. Burst pacing from the quadripolar catheter inside the right ventricle
induced unsustained VT. Both the left and right ventricles were mapped using the Rhythmia mapping system (Boston Scientific, Cambridge, Massachusetts) and Intellamap Orion mapping catheter (Boston Scientific). The earliest activation was noted at the septal wall of the right ventricular outflow tract (RVOT) just below the pulmonary valve. On the left side, the high septum of the left ventricle just below the aortic valve was the earliest activation site. Pace mapping was also performed, and the paced morphology was 96% matched to the clinical VT.

Two Intellanav MIFI (Boston Scientific) open-irrigated RF ablation catheters were connected to a standard biphasic defibrillator through the modified cable adapter (Figure 1). One of the catheters was placed on the RVOT septal wall just beneath the pulmonary valve, and the other was placed on the left ventricular outflow tract (LVOT) septal wall just below the aortic valve. The catheter tips were positioned 1.5 cm apart from each other to create a vector across the VT target (Figures 2 and 3). The catheter positions were confirmed by using 3D mapping, fluoroscopy, and intracardiac echocardiography (Figure 4).

DC ablation was initiated at 70 J, which was discharged simultaneously from both catheters in synchrony with the R-wave. The patient went into temporary atrial flutter and then spontaneously converted to normal sinus rhythm. Repeated mapping showed persistence of voltage and electrograms in the ablated region. Three more DC ablations with synchronized biphasic energy of 100 J were applied to the same location. The final map then showed a different activation pattern with lower voltage in RVOT toward the pulmonic valve (Figure 5). Aggressive pacing with up to triple extra stimuli did not reproduce VT. The patient was discharged the next day with no immediate complications.

**DISCUSSION**

The technique of cardiac ablation using direct electric current was developed in the 1980s to ablate the atrioventricular node for the treatment of refractory supraventricular arrhythmia (1). The average amount of energy used was extremely high. In a study of 49 patients who received DC ablation, the average amount of energy required for successful ablation was 661 ± 360 J, and atrioventricular block was achieved with a success rate of 89.5% in 42 of 49 patients. However, an extremely high amount of energy and lack of arc control resulted in numerous complications such as myocardial stunning, catheter tip gas explosion with embolic complications, and adjacent tissues injuries (2). According to data from the Percutaneous Cardiac Mapping and Ablation Registry published in 1988, there were 8 cases of sudden death among a total of 480 patients (1.8%) who underwent the procedure, and most of them died within
6 months post-procedure (3). Thus, DC ablation fell out of favor, especially with the subsequent development of RF ablation in the early 1990s (4). However, RF ablation carries its own limitations. It is less effective for ablating deeper myocardial substrates and has complications such as “steam pop” from excessive thermal energy, cardiac perforation/tamponade, pulmonary vein stenosis, and adjacent coronary artery injury (5).

Recently, DC ablation has been reinvestigated as an alternative source of energy in cardiac ablation with the advancement in catheter technology where the catheter can deliver relatively low energy as well as low current density without creating an arc (6). The mechanism of DC ablation is disruption of cell membranes using electrical energy, resulting in apoptosis (7). An animal study showed 100- to 300-J-unipolar DC ablation resulted in larger and deeper lesions (8 to 10 mm) than standard RF ablation (4 to 5 mm) (8). Coronary luminal diameters were also unaffected by DC ablation in porcine models (9). Recently, Lavee et al. (10) proposed an ablation modality for atrial arrhythmia using biphasic DC in animal models. Unfortunately, there have been no data in humans about the efficacy and safety for VT. This study reports the first-in-human case of VT ablation using biphasic DC with short-term success and no procedural complications.
**FOLLOW-UP**

The present patient had recurrent VT at 4 months following the procedure. He underwent a second DC ablation with short-term success. However, his VT returned 2 months later. No procedure-related complication have been reported at this writing during 1-year follow-up.

**CONCLUSIONS**

With the advancement in catheter technology that allows the use of minimal current density and energy, the current risk profile of DC ablation is significantly lower than its predecessors from the 1980s. DC ablation may be considered an alternative tool in electrophysiologists’ armory for ablation of deep substrate arrhythmia, but further studies and longer follow-up examinations are warranted for its efficacy and safety.

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**KEY WORDS** direct-current ablation, electrophysiology, ventricular arrhythmia
Coronary Arterial Vasospasm
A Rare Complication of Vein of Marshall Ethanol Infusion for Atrial Fibrillation

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ABSTRACT
A 75-year-old man was admitted for repeat ablation of atrial fibrillation. At 30 min after infusion of 3.5 ml of ethanol into the vein of Marshall, inferior ST-segment elevation with coronary arterial vasospasm was observed. This is the first report of coronary vasospasm after chemical ablation of the vein of Marshall. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1766-70) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION
A 75-year-old man with symptomatic drug-refractory atrial fibrillation (AF) and with recurrent AF after previous AF ablation was admitted for repeat catheter ablation.

PAST MEDICAL HISTORY
Other than AF, the patient had no cardiac history and no coronary artery disease risk factors. He denied symptoms concerning for angina. The patient had no family history of a cardiac disorder or sudden death.

INVESTIGATIONS
The patient was brought into the electrophysiology laboratory for repeat ablation. All 4 pulmonary veins

LEARNING OBJECTIVES
- Coronary vasospasm is a rare potential complication of ethanol ablation of the VOM. Because it can take time for completion of lesion formation after ethanol infusion, it may be prudent to monitor patients for 30 to 45 min after ethanol ablation.
- ST-segments should be monitored closely on 12-lead ECG during and after ethanol ablation.
- Limiting the dose of the ethanol infusion (1.0 to 1.5 ml over 90 to 120 s) could help prevent this complication.
- Pre-procedure computed tomography and electroanatomic mapping can delineate the relationship of the VOM with the coronary arteries and other collateral structures.

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(PVs) were chronically isolated; during isoproterenol infusion, recurrent premature atrial contractions were seen that occasionally triggered AF. These premature atrial contractions were noted to be earliest at the distal coronary sinus (CS). Detailed activation mapping identified the site of origin of this premature atrial contraction to be from the left atrial (LA) endocardial aspect of the vein of Marshall (VOM). Therefore, VOM ethanol ablation was performed to target non-PV triggers. To delineate the anatomy of the CS, occlusive balloon venography of the CS was performed. The VOM was visualized in the right anterior oblique projection. To cannulate the VOM, both outer (CPS DirectTM 47 cm, Abbott, St. Paul, Minnesota) and inner (CPS AIMTM 59 cm, Abbott) CS delivery sheaths were used from the right internal jugular vein. After VOM venography, an angioplasty wire (ATHLETE Premium, Japan Lifeline, Tokyo, Japan) and an angioplasty balloon (15-mm length, 1.5-mm diameter, Emerge PTCA Dilatation Catheter, Boston Scientific, Marlborough, Massachusetts) were advanced into the VOM as distally as possible. In this case, the length of the VOM was very short (11 mm), and a total of 3.5 ml of 98% ethanol was infused slowly over 90 s from the VOM ostium during balloon dilation (Figure 1, Video 1). Electroanatomic bipolar voltage mapping confirmed a localized low-voltage zone (<0.1 mV) on the endocardial left atrium across from the VOM ostium during balloon dilation. Because of the LCx vasospasm seen on coronary angiography, intravenous infusion of a vasodilator (2 mg isosorbide dinitrate) was administered, which resolved in resolution of ST-segment elevations (Figure 2C) and hemodynamic stability.

**DIFFERENTIAL DIAGNOSIS**

The differential diagnosis of ST-segment elevation in the inferior leads during AF ablation includes air embolism, LA embolism to the right coronary artery (RCA), coronary vasospasm, and acute pericarditis.

**INVESTIGATIONS**

Arterial access was obtained, and urgent coronary angiography was performed, which revealed focal coronary vasospasm of the distal left circumflex coronary artery (LCx #14 posterolateral branch) (Figure 3, Videos 2 and 3). Using CARTO Merge software (Biosense Webster, Irvine, California), the course of the coronary arteries from pre-procedure computed tomography imaging were merged onto the LA electroanatomic map. The endocardial LA low-voltage area that resulted from VOM ethanol ablation overlapped with the anatomic location of the spastic distal LCx artery (Figure 4).

**MANAGEMENT**

Because of the LCx vasospasm seen on coronary angiography, intravenous infusion of a vasodilator (2 mg isosorbide dinitrate) was administered, which resulted in resolution of ST-segment elevations (Figure 2C) and hemodynamic stability.

**DISCUSSION**

To the best of our knowledge, this is the first report of coronary arterial vasospasm after coronary venous ethanol ablation of the VOM during AF ablation. Recently, the VOM has been increasingly recognized to be a potential target site during AF ablation to achieve mitral isthmus block (1–3), vagal denervation (4), and for targeting non-PV triggers (5–7) and

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**ABBREVIATIONS AND ACRONYMS**

- AF = atrial fibrillation
- CS = coronary sinus
- ECG = electrocardiogram
- LA = left atrial
- LCx = left circumflex coronary artery
- PV = pulmonary vein
- RCA = right coronary artery
- VOM = vein of Marshall
Marshall bundle-related atrial tachycardia (8). In those reports (1,4,6,8), 2 CS and 2 VOM dissections were observed during ethanol chemical ablation procedures, whereas no pericardial effusions or other major complications, including coronary artery abnormalities, were observed in a total of 97 cases. Depending on the length of the VOM, up to 3 or 4 balloon occlusive injections of 98% ethanol (1.0 to 1.5 ml over 90 to 120 s; total, 3.0 to 6.0 ml) were subsequently delivered in general (1,5). However, in our case, in view of the very short length of the VOM (11 mm), we instead delivered a total of 3.5 ml of ethanol at 1 time. Given the short length of the VOM, there was concern that the catheter could dislodge during ethanol infusion. Because of the technical difficulty in cannulating the VOM (possibly precluding repeated ethanol injections), we decided to give a single 3.5-ml infusion, rather than deliver multiple infusions of smaller doses. It is possible that this larger amount of ethanol may have resulted in a larger area of dispersion into the LA wall and increased the risk for coronary vasospasm. Coronary vasospasm can be induced by parasympathetic activity, and therefore, stimulation of the left inferior ganglionated plexi is a possible cause of the vasospasm. One relatively common cause of transient inferior ST-segment elevation during left-sided cardiac procedures in supine patients is air embolism.

FIGURE 2 Electrocardiograms

(A) Baseline. (B) Inferior ST-segment elevation 30 min after a 98% ethanol infusion. (C) Post-vasodilator injection.
into the RCA. However, this was ruled out by urgent coronary angiography, which showed focal coronary vasospasm in the distal LCx (with a widely patent RCA), and the ST-segment elevation resolved after the administration of a vasodilator. Furthermore, the CARTO Merge software revealed the location of the spastic artery to be within the area of the LA endocardial bipolar scar resulting from the ethanol ablation. Although one cannot exclude the possibility that rapid ethanol injection of 3.5 ml all at once may have resulted in ethanol reflux into the left atrium, thus eventually entering the RCA causing transient RCA vasospasm, the finding that coronary angiography in the presence of ST-segment elevations showed a widely patent RCA casts doubt on RCA vasospasm as the cause. For these reasons, the coronary spasm appeared to be a direct complication of VOM ethanol ablation. Interestingly, the coronary spasm occurred 30 min after ethanol infusion in the VOM, which matched the time frame for completion of lesion formation extending from the posterior LA wall to the left inferior PV, as reported by Valderrában et al. (4). This case supports the notion that the full effects of ethanol ablation can take time to occur after the infusion.

**FOLLOW-UP**

After more than 1 year of follow-up, this patient has not experienced any recurrent arrhythmia symptoms or chest pain and has received no medical therapy to prevent recurrence of vasospasm. The 24-h ambulatory ECG monitoring has not detected any arrhythmias.

**CONCLUSIONS**

Our case is the first clinical report to describe coronary arterial vasospasm after coronary venous ethanol ablation during AF ablation. Although ethanol infusion into the VOM can be an effective strategy to achieve long-term freedom from recurrent AF, operators should be cognizant of the potential complications, including coronary vasospasm.

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KEY WORDS atrial fibrillation, chemical ablation, coronary vasospasm, ethanol, vein of Marshall

APPENDIX For supplemental videos, please see the online version of this paper.
Left Pericardiophrenic Vein Pacing for Tachy-Brady Syndrome Due to an Obstructing Cardiac Angiosarcoma

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ABSTRACT

We describe a case of a permanent pacemaker lead placement via the left pericardiophrenic vein for the treatment of tachy-brady syndrome due to a primary cardiac angiosarcoma. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1771-5) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

PRESENTATION

A 56-year-old woman with a history of hypothyroidism was transferred to the authors’ hospital after presenting to an outside institution with a 3- to 4-month history of progressive dyspnea and left-sided rib pain, as well as a 30-lb unintentional weight loss over the preceding 6 months. A right atrial filling defect was seen on her transthoracic echocardiogram at the outside institution, which was initially thought to be a thrombus. On admission, the patient was hemodynamically stable with a blood pressure of 134/61 mm Hg, a heart rate of 54 beats/min, a respiratory rate of 16 breaths/min, and oxygen saturation of 98% on room air. A physical examination was significant only for point tenderness of the rib under her left breast with no appreciable cardiac murmurs. There were no initial laboratory abnormalities. During her hospitalization, she had frequent paroxysms of atrial fibrillation and atrial tachycardia with ventricular rates ranging from 180 to 200 beats/min followed by prolonged, symptomatic conversion pauses of 4 to 5 s, as well as junctional bradycardia with rates of 30 to 40 s (Figures 1A to 1C). She was initially treated with low-dose metoprolol and amiodarone for rate control and potential suppression of episodes of atrial arrhythmia, however, this further exacerbated the symptomatic conversion pauses and episodic bradycardia.

LEARNING OBJECTIVES

• To recognize cardiac tumors as a potential cause of both tachyarrhythmias and bradyarrhythmias.
• To highlight cardiac vein anatomy as it relates to alternative positions for pacemaker lead placement.
Multiple Electrocardiograms Demonstrating the Patient’s Various Arrhythmia Episodes

(A) Supraventricular tachycardia (SVT) with conversion to junctional bradycardia.

(B) Atrial fibrillation with rapid ventricular response.

(C) Junctional bradycardia.
**MEDICAL HISTORY**

The patient had a medical history of hypothyroidism on levothyroxine with a family history of malignancy including lung cancer (mother) and melanoma (father).

**DIFFERENTIAL DIAGNOSIS**

Considering that the patient was a relatively healthy middle-aged woman, the differential diagnosis of her progressive dyspnea over a 3- to 4-month period included new-onset cardiomyopathy, however, her unintentional weight loss raised suspicion for malignancy.

**INVESTIGATIONS**

Workup included a transthoracic echocardiogram, which showed a right atrial mass with poor definition of its borders (Figure 2). Cardiac magnetic resonance showed a large, solid, and nearly completely enhancing soft tissue mass, the bulk of which was located in the posterior septal wall of the right atrium measuring approximately $4.7 \times 4.7 \times 7.5$ cm (Figure 3). The mass spanned the mid to lower superior vena cava (SVC) into the low, right atrium near the border with the inferior vena cava (IVC) but did not fully obstruct IVC inflow or the coronary sinus. There was extracardiac spread of the mass into the pericardial space surrounding the posterior right lateral circumference of the aorta as well as the upper lobe branches of the right pulmonary artery and at least 1 of the branches of the right upper pulmonary vein. The mass also extended around the right lateral aspect of the left atrium to the level of the incoming coronary sinus. In addition, there was complete atelectasis of the right middle lobe, likely due to mass effect, as well as extension around the right middle lobe bronchus. Preliminary diagnosis based on the cardiac magnetic resonance was that of an angiosarcoma. As a tissue diagnosis was required for treatment planning, the patient underwent transesophageal echocardiography-guided biopsy.
(Figure 4), which confirmed the diagnosis of an angiosarcoma.

**MANAGEMENT**

Given the patient’s symptomatic tachy-brady syndrome, implantation of a permanent pacemaker (PPM) was the definitive treatment option. As there was an inability to place a conventional temporary or permanent pacing system due to SVC and IVC obstruction from the mass with deferment of a thoracotomy for epicardial lead placement due to the potential need for additional thoracic surgery in the future, an individualized approach to pacing was required to prevent symptomatic bradycardia and conversion pauses. Computed tomography of the chest with upper extremity venography revealed an accessory epicardial/pericardial vein extending from the left brachiocephalic vein along the left ventricle, consistent with the left pericardiophrenic vein (LPPV) (Figure 5).

The patient underwent implantation of a single-chamber PPM with placement of a bipolar left ventricular lead in the LPPV (Figures 6 and 7). Multiple pacing locations were mapped along the course of the LPPV, testing at various outputs and pulse widths; however, every location where there was ventricular capture, there was concomitant phrenic nerve capture. Because the patient’s predominant symptoms were related to conversion pauses and because brief periods of phrenic nerve stimulation were not excessively uncomfortable for the patient, keeping in mind the desire to avoid an additional procedure (surgical epicardial lead placement), the decision was made to place the bipolar lead in the location with the lowest threshold and use it for demand ventricular pacing at a rate of 30 beats/min. After PPM implantation, antiarrhythmic therapy was increased with improvement in the patient’s tachyarrhythmia episodes with only minimal ventricular pacing.
DISCUSSION

Primary cardiac angiosarcoma is a rare cardiac malignancy with a typically poor prognosis (1). The age at diagnosis is generally in the third to fifth decade of life, and the median survival is <10 to 24 months with incomplete and complete resection, respectively (1-4). Presenting symptoms can include unexplained weight loss, dyspnea, thoracoabdominal pain, syncope, peripheral edema, heart failure, and palpitations (5). Given the tumor’s predilection for the right atrium (3), mass effect can lead to vena caval obstruction, arrhythmia, and potential conduction disturbances (4). SVC and IVC obstructions can pose a unique problem when symptomatic conduction disturbances occur due to infiltration of a tumor into the cardiac conduction system. Without direct access to the right-sided cardiac chambers through the vena cavae for temporary or permanent pacing, an unconventional approach should be considered and sought, as was shown in the present case. The LPPV is a vessel located on the lateral border of the heart and courses adjacent to the pericardium and drains the right-sided cardiac chambers through the vena cavae for temporary or permanent pacing, unconventional access may be considered. Although it is not an ideal route for pacing given its proximity to the left phrenic nerve, the LPPV facilitated treatment of both bradycardia and atrial tachyarrhythmia.

After 8 months of neoadjuvant chemotherapy, the patient underwent surgical resection of the angiosarcoma with reconstruction of the right atrium and SVC at another institution. Following this procedure, the patient underwent surgical resection of the angiosarcoma with reconstruction of the right atrium and SVC at another institution. Following this procedure, the burden of phrenic nerve stimulation increased. Pacemaker system revision was performed in which the LPPV lead was removed and replaced with a His bundle lead, a procedure facilitated by the newly reconstructed anatomy.

Right atrial obstruction can complicate the treatment of symptomatic bradycardia. Without access to the right-sided cardiac chambers for pacing, unconventional access may be considered. Although it is not an ideal route for pacing given its proximity to the left phrenic nerve, the LPPV facilitated treatment of both bradycardia and atrial tachyarrhythmia.

CONCLUSIONS

Right atrial obstruction can complicate the treatment of symptomatic bradycardia. Without access to the right-sided cardiac chambers for pacing, unconventional access may be considered. Although it is not an ideal route for pacing given its proximity to the left phrenic nerve, the LPPV facilitated treatment of both bradycardia and atrial tachyarrhythmia.

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KEY WORDS: bradycardia, cancer, cardiac magnetic resonance, cardiac pacemaker, computed tomography, electrophysiology, imaging, supraventricular arrhythmia, weight loss.
Noninvasive 3D Mapping and Ablation of Epicardial Premature Ventricular Contractions From the Endocardial Aspect of the Left Atrial Appendage

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ABSTRACT

Ablation is an established treatment for ectopy originating from the left ventricle (LV). We report on a case of noninvasive 3-dimensional mapping locating the origin precisely in the epicardial LV summit area. However, after failed attempts from LV and epicardially, ablation via the left atrial appendage was finally successful. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1776–80) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Learning Objectives

- To use personalized 3D information from noninvasive 3D mapping and a CT roadmap that locates the origin of ventricular arrhythmias and guides the operator to find the optimal access to an ablation target.
- To consider ablation through the LAA to reach the epicardium of the LV summit, when endocardial ablation fails and/or an epicardial approach seems difficult.

An 18-year-old female patient with a structurally normal heart and frequent monomorphic premature ventricular contractions (PVCs) and episodes of nonsustained ventricular tachycardia (VT) since childhood was admitted for catheter ablation because for frequent palpitation refractory to medical therapy.

PAST MEDICAL HISTORY

The patient had been treated for several years with beta-blockers, as well as flecainide.

DIFFERENTIAL DIAGNOSIS

Screening for cardiomyopathy was negative.

INVESTIGATIONS

Before the admission, a 24-h Holter showed a high PVC burden (42%) and several episodes of nonsustained VT despite antiarrhythmic therapy with metoprolol 100 mg once daily and flecainide 150 mg.
once daily. The electrocardiogram (ECG) on admission is shown in Figure 1.

A contrast-enhanced computed tomography (CT) scan excluded significant coronary artery disease or anomaly and was also used to reconstruct a 3-dimensional (3D) model of the heart on the electro-anatomical mapping system (CARTO 3, Biosense Webster, Brussels, Belgium) for 3D image integration to guide as a roadmap.

MANAGEMENT

NONINVASIVE MAPPING. Before the invasive procedure, the patient underwent noninvasive mapping using the VIVO system (Catheter Precision, Inc, Ledgewood, New Jersey) (1,2). On the day before the procedure, a 12-lead Holter (Mortara, Hill-Rom, Chicago, Illinois) was fitted for 14 h that recorded the clinical PVC morphology. To precisely locate the PVC origin, the exact position of the ECG leads on the patient’s chest was recorded using a 3D camera. All data (ECG, patient-specific 3D heart and torso model, plus 3D photograph of ECG positions) were combined to create a noninvasive activation map that identified the earliest point of activation during PVC. VIVO determined the PVC origin at the epicardial aspect of the left ventricular (LV) summit, right above the mitral valve annulus (Figure 2).

INVASIVE ABLATION PROCEDURE. At the beginning of the ablation, the patient was in sinus rhythm with frequent monomorphic PVCs. After gaining venous and arterial femoral accesses under ultrasound guidance, a 3.5-mm irrigated tip ablation catheter (NAVISTAR ThermoCool, D/F SF ST, Biosense Webster) was advanced retrogradely and a fast anatomical mapping of the descending aorta and aortic arch was performed in combination with 3D image of the pre-acquired CT scan (Figure 3). Subsequently, a fast anatomical mapping and pace-map of the left ventricular outflow tract (LVOT) and the LV summit was carried out (PASO module, CARTO 3 V7, Biosense Webster). The best pace-map match from the endocardial aspect of the LV summit was 91% without any real prematurity of the local bipolar signal. Therefore, the distal coronary sinus (CS) was mapped to get better access to the corresponding epicardial LV summit region, which

**FIGURE 1 12-Lead Electrocardiogram**

12-lead electrocardiogram in sinus rhythm with monomorphic premature ventricular contractions (PVCs) in a trigemini pattern (25 mm/s, 10 mm/mV).
resulted in a pace-map match of 96%. Radiofrequency ablation at this site (20 W, 8 ml/min) resulted in initial suppression of the PVCs for the duration of the energy delivery, which, however, recurred despite several ablation attempts.

When reviewing the entire anatomy, we noticed that the left atrial appendage (LAA) was overlapping the area of earliest activation and best pace-map match in the LV and CS. Given the suspicion of a “true” epicardial origin of the clinical PVC not reachable via the LV endocardium or the distal CS, the overlapping LAA would potentially make a subxiphoid epicardial approach difficult. We therefore attempted an endocardial ablation via the LAA using a transseptal access. Mapping the anterior-inferior aspect of the LAA, discrete premature signals with earliest local activation –41 ms before the QRS complex onset were observed (Figure 3). Three radiofrequency ablations (20 W, 8 ml/min) at this site resulted in the instant suppression of the PVC; however, with recurrence within a few minutes. Thus, radiofrequency energy was carefully increased up to 35 W in the presence of good contact force toward the LV epicardium, with final complete elimination of the clinical PVC. No further PVC or VT was inducible during a waiting time of 45 min (total procedure duration 238 min, total fluoroscopy time 4 min 15 s).

**DISCUSSION**

Ablation of ventricular arrhythmias should be considered in patients without structural heart disease when symptomatic or when medications are ineffective (3). In this case, the patient was very symptomatic with a high burden of PVC despite optimal antiarrhythmic therapy. The LV summit is the most superior epicardial region of the LV bounded by the left anterior descending and left circumflex coronary artery. It accounts as an origin for up to 14.5% of LV arrhythmias. Ventricular arrhythmias originating from the LV summit are known to be difficult targets for ablation; the reasons being multifactorial, including submural or subepicardial focal origins that are difficult to reach endocardially and the close proximity to coronary arteries and surrounding fat precluding successful subxiphoid epicardial ablation (4,5). Attempts at ablation of this area have often been carried out via surrounding structures including septal leftward aspects of the right ventricular outflow tract, aortic cusp region, great cardiac veins, and basal LV endocardium (6,7). Ablation of an arrhythmia focus in this area via the LAA has been described in only a few reports (8–10).

In our case, 12-lead ECG morphology of the ectopic focus was suggestive of LV summit origin with a nonspecific bundle branch block morphology with...
initial R-wave in lead V1, negative polarity with Q-wave in lead I, and QS pattern in lead aVL. The noninvasive pre-procedural 3D mapping with VIVO confirmed this location taking the individual 3D anatomy of the patient into account. The key information, however, came from the 3D reconstruction of the pre-procedure CT scan that served as a roadmap. It demonstrated the close relationship of the LAA overlapping the LV summit area with clear depiction of the triangle between the coronary arteries.

The combination of both roadmap and noninvasive 3D mapping assisted in understanding the individual anatomy and finally guided the operator to the optimal site to achieve complete elimination of the PVC located in the epicardial LV summit. To the best of our knowledge, this is the first reported case describing this approach.

In addition, using these advanced mapping techniques potentially facilitates a number of aspects of such procedures: 1) reduction of procedure duration because the 3D activation map can be done non-invasively on the ward without exposing the patient to the time-consuming sequential mapping (which may be especially relevant in patients with rare PVCs); 2) reduction of radiation exposure, as the 3D roadmap can be merged using the aortic arch as a
reference; and 3) potential to reduce periprocedural complications by avoiding the coronary arteries and/or the need of a subxiphoid epicardial approach.

Interestingly, it took 4 radiofrequency applications in the LAA with titration of energy to up to 35 W (applied for max 120 ms) and good contact force to persistently eliminate the PVC, creating finally an adequate transmural lesion through the wall of the LAA to reach the epicardially located origin. The risk of perforation must be carefully considered while ablating in the LAA and careful energy titration is recommended. Because of the full heparinization of our patient, the alternative subxiphoid epicardial approach (with its potential for complications and added financial burden from longer post-procedural hospitalization) would have been needed to be carried out as a second procedure.

**FOLLOW-UP**

After ablation, the patient remained in sinus rhythm and no further episodes of PVCs or VTs were detected on 24-h telemetry. A bedside transthoracic echocardiography excluded any significant pericardial effusion and the patient was discharged off antarrhythmic medication on the post-procedural day. No relevant PVCs have been since recorded during 48-h follow-up Holter recordings 6 months later, and the patient remained asymptomatic.

**CONCLUSIONS**

We present a case of a successful ablation of PVC originating from the epicardial LV summit via the LAA. Careful preprocedural planning with noninvasive 3D mapping, appropriate 3D roadmap imaging, and detailed electroanatomical mapping all aided this successful outcome.

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**KEY WORDS** ablation, electroanatomical mapping, ventricular tachycardia
MINI-FOCUS ISSUE: ARRHYTHMIAS AND EP

CASE REPORT: CLINICAL CASE

Long-Term Follow-Up of Cardioneuroablation to Treat Second-Degree Block After Slow Pathway Ablation

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ABSTRACT

We present the long-term follow-up of a 31-year-old woman who underwent cardioneuroablation (for atrioventricular (AV) block. Slow pathway ablation was performed in September 2017 with normal follow-up until April 2018, when the patient started noticing symptoms of palpitations at rest, and the electrocardiogram showed a Mobitz I AV block. A cardiac stress test and 24-h Holter monitoring demonstrated first- and second-degree block and normal AV conduction during times of higher heart rate. (Level of Difficulty: Advanced.) (J Am Coll Cardiol Case Rep 2020;2:1781–8) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

The patient was a symptomatic 31-year-old woman with no comorbidity who presented with new symptoms of palpitations, fatigue, dizziness, and irregular cardiac rhythm on physical examination. She underwent cardioneuroablation (CNA) to treat a first- and second-degree atrioventricular (AV) block that occurred after undergoing slow pathway ablation (SPA) 9 months earlier.

PAST MEDICAL HISTORY

The patient described a long history of tachycardic palpitations with shortness of breath and the need to perform vagal maneuvers or go to the emergency department (ED) to convert tachycardia to sinus rhythm. Treatment with beta-blockers and propafenone failed, and the patient was referred back to our center (Santa Rita de Cassia Hospital) to perform...
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Follow-Up of CNA for Second-Degree Block After SPA

ABREVIATIONS AND ACRONYMS
AV = atrioventricular
CNA = cardioneuroablation
ED = emergency department
EPS = electrophysiological study
FFT = fast Fourier transform
SPA = slow pathway ablation
catheter ablation of supraventricular tachycardia. In September 2017, the patient underwent SPA with success and no complications. Eight months later, she started experiencing fatigue, dizziness, fainting, and abnormal heartbeats. She became highly symptomatic and went to the ED, where she was found to have an irregular cardiac rhythm with several pauses during auscultation. The electrocardiogram at this time showed a first-degree AV block.

DIFFERENTIAL DIAGNOSIS

After the ED visit, during a regular appointment, a new resting electrocardiogram (Figure 1) was performed. Second-degree Mobitz I block was diagnosed (documentation of consecutive AV prolongation). In normal and young patients, the obvious diagnosis would be a functional AV block. However, in our case, the first thought was a lesion in the fast pathway because the patient no longer reported her previous symptoms.

INVESTIGATIONS

The patient underwent a stress treadmill test and 24-h Holter monitoring to detect higher degrees of AV block. Holter monitoring showed the presence of first- and second-degree AV blocks, including a 2:1 AV block during sleep (Figure 2) and normal AV conduction when the heart rate was higher (Figure 3, Table 1). To our surprise, there was an improvement in AV conduction during higher exercise velocity in the Ellestad protocol, a change suggesting parasympathetic behavior of the AV node. On the basis of these findings, in June 2018, we decided to perform CNA.

DISCUSSION

Three main parasympathetic ganglia are found outside the atrial wall in paracardiac fat pads that provide innervation to the heart (2), and they are subdivided into ganglia A, B, and C. Ganglion A is located between the aorta and the superior vena cava (Figure 7), ganglion B is located between the right pulmonary veins and the right atrium (Figures 4 to 6), and ganglion C is located between the inferior vena cava and at the wall between the right atrium and left atrium (Figures 4 to 6). Ganglion A appears to be the most important of the vagal fibers, traveling to the atria and to the sinus and AV nodes. Bilateral vagal fibers to the sinus and AV nodes converge first at ganglion A and then project to ganglia B and C, which provide vagal innervation to the sinus and AV nodes, respectively.

Before CNA, we performed a basal electrophysiological study (EPS) and administered 3 g of atropine to prove that the AV conduction normalized during the drug effect. After that, we conducted a new EPS with and without atropine. Major EPS findings pre-ablation were normal. Her His-ventricle interval was normal, with no AV jump or echo beats. There was an increase in heart rate after atropine by 114%, from 56 to 103 beats/min, and there was normal AV conduction. The Wenckebach point decreased from 520 to 410 ms, and the AV refractory period decreased from 500 to 310 ms before and after atropine, respectively. Finally, at this point we started the ablation procedure. Electrical targets for ablation were high frequency, and long fractionated signals were seen in the distal and proximal catheter dipoles and at abnormal FFT signals. Heart rate increase during radiofrequency applications was higher at these sites than at other sites without these characteristics.

After CNA, the final heart rate was 97 beats/min (Figure 8). EPS with and without atropine showed no heart rate increase, a Wenckebach point at 430 ms, and an atrial refractory period of 340 ms, thereby displaying a loss of parasympathetic behavior.
Atrioventricular block with progressive atrioventricular prolongation.
these patients still experienced nocturnal Mobitz type I AV block after the procedure. Long-term follow-up results presented in another study concluded that endocardial radiofrequency ablation of neurally mediated reflex syncope through both atria has excellent results in some patients and may prevent the need for pacemaker implantation.

Anatomically mediated CNA has been increasingly used to treat severe vagally related arrhythmias worldwide. Although guidelines indicate pacemaker implantation for cases of symptomatic AV block, when patients are mostly young and otherwise healthy, we encourage a conservative approach. The intrinsic cardiac nervous system forms a complex neural network composed of the ganglia plexus and interconnecting axons. Larger ganglia are observed close to the pulmonary vein and serve as autonomic integration centers, modulating cardiac excitability. This widely distributed structure cannot be entirely targeted. A comprehensive and selective approach is required and is meant to promote attenuation instead of total vagal blockade, and a step-by-step test with extracardiac vagal stimulation can be a much wiser approach to management during this type of

FIGURE 2 Holter Monitoring

Second-degree atrioventricular block (Mobitz I [Wenckebach]) at the top and a 2:1 atrioventricular block at the bottom (lower heart rate of 44 beats/min during sleep).
procedure. With anatomic knowledge and previous descriptions, Aksu et al. (8) successfully performed a similar procedure to treat 2:1 AV block induced after an SPA in a 54-year-old woman. The major difference between the 2 approaches was that we targeted the 3 ganglia localized in both atria because of their interactions. The pitfall of our method was the atropine test performed during the procedure, before CNA.

![FIGURE 3 Holter Monitoring](image)

Higher rate with normal atrioventricular conduction.

| TABLE 1 Pre- and Post-Ablation 24-h Holter Monitoring |
|------------------------------------------------------|
| **24-h Holter Monitoring** | **Heart Rate, beats/min** | **Long Pause, s** | **First-Degree Block** | **Second-Degree Block** | **High-Degree Block** | **SDNN, ms** | **PNN50, ms** |
|--------------------------|---------------------------|-----------------|------------------------|------------------------|------------------------|--------------|--------------|
| Pre-ablation             | 44                        | 72              | 126                    | 2.13                   | Yes                    | Yes          | Yes          | 123          | 25           |
| 7 days                   | 57                        | 83              | 124                    | 1.12                   | No                     | No           | No           | 114          | 1.15         |
| 30 days                  | 54                        | 80              | 139                    | 1.31                   | No                     | No           | No           | 138          | 1.38         |
| 6 months                 | 62                        | 79              | 131                    | 0.97                   | No                     | No           | No           | 83           | 0.3          |
| 12 months                | 51                        | 74              | 120                    | 1.34                   | No                     | No           | No           | 127          | 1.76         |
| 18 months                | 54                        | 76              | 132                    | 1.11                   | No                     | No           | No           | 88           | 1            |
| 24 months                | 56                        | 81              | 140                    | 1.07                   | No                     | No           | No           | 82           | 1            |

PNN50 = proportion of NN50 divided by the total number of NN (R-R) intervals; SDNN = standard deviation of the NN (R-R) intervals.
The major explanation for this is that the atropine test is not a procedure that can be done routinely in public and private hospitals in Brazil. However, the way that we addressed the vagal ablation response, even with the residual atropine effect, is the heart rate increase during radiofrequency application. In this specific case we show the 2-year follow-up of the patient that may prove that the AV conduction was normalized and stayed normal after the procedure.

Targeting all the ganglionated plexus could be a risk if continuous monitoring by extracardiac vagal stimulation is not performed because AV block can become more severe if you denervate only the sinus node with the heart rate increase. Therefore, an individualized approach to ensure the objectives and success of the CNA is mandatory.

**FOLLOW-UP**

This is 1 of few reported cases of catheter ablation-based treatment to improve AV conduction to avoid pacemaker implantation. Like the case reported by Bulava et al. (9), our case involved a young woman with second-degree AV blocks after an SPA. The 2 cases showed complete resolution of the AV blocks at times of higher heart rate and after atropine infusion. Our follow-up was longer and included 24-h Holter monitoring at 7 and 30 days and at 6, 12, 18 and 24 months. Follow-up results were completely within normal parameters, thereby showing that the CNA approach resulted in successful treatment.
CONCLUSIONS

As in other investigators’ case series, our results of CNA for the treatment of functional sinus bradycardia and AV blocks are encouraging and excellent. They enable us to avoid pacemaker implantation in a selected group of patients.

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KEY WORDS

ablation, bradycardia, cardiac pacemaker, electroanatomic mapping
CASE REPORT: CLINICAL CASE

Recurrent Left Pleural Effusion Following Left Atrial Appendage Closure With the Watchman Device

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ABSTRACT

A 75-year-old woman with recent left atrial appendage closure with the Watchman device (Boston Scientific, Natick, Massachusetts) presented with recurrent left pleural effusion. The constellation of chest pain, pericardial effusion, and exudative pleural effusion were suggestive of an inflammatory process precipitated by microperforation of the fixation anchors during the Watchman placement. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1789–92) © 2020 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

A 75-year-old woman with recent left atrial appendage closure (LAA) with the Watchman device (Boston Scientific, Natick, Massachusetts) 2 months before presentation was referred to our hospital for evaluation of progressive shortness of breath and chest pressure in the setting of recurrent left pleural effusion. Her symptoms started following her LAA closure procedure and progressed in severity requiring multiple emergency department visits and a prior hospitalization with 2 thoracenteses draining clear fluid from her left pleural space. She also reported subjective fevers and 20-pound weight loss that she attributed to lack of appetite from the severity of her symptoms.

PAST MEDICAL HISTORY

The patient had a history of paroxysmal atrial fibrillation and LAA closure with Watchman, hypertension, dyslipidemia, well-controlled diabetes mellitus type 2 (hemoglobin A1c 6.6%), and chronic kidney disease. Her home medications included aspirin, bisoprolol, evolocumab, ferrous sulfate, fluoxetine, gabapentin, rosuvastatin, semaglutide, and furosemide.

DIFFERENTIAL DIAGNOSIS

Differential diagnoses include Watchman erosion to the pericardial and pleural spaces, Watchman-related inflammatory process, pulmonary embolism, drug-induced pleural effusion, malignancy, and connective tissue disease.

INVESTIGATIONS

Chest radiograph on admission showed reaccumulation of the previously drained left pleural effusion (Figure 1A) for which she underwent placement of a chest tube and drainage of a clear yellow exudative pleural fluid with lymphocyte...
Pleural Effusion After LAA Closure With Watchman SEPTEMBER 2020:1789-92

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ABBREVIATIONS AND ACRONYMS

CT = computed tomography
hs-CRP = high-sensitivity C-reactive protein
LAA = left atrial appendage
NSAID = nonsteroidal anti-inflammatory drug

prevalence. The detailed pleural fluid analysis was as follows: white blood cells 425 cells/µl, right blood cells 7,123 cells/µl, neutrophils 12%, lymphocytes 50%, eosinophils 1%, total protein 3.8 g/dl, glucose 176 mg/dl, cultures negative for any infection, and cytology negative for any malignant cells. Her laboratory tests were notable for chronic anemia and elevated high-sensitivity C-reactive protein (hs-CRP) at 63.9 mg/l. Chest computed tomography (CT) showed multiple subcentimeter lung nodules, not fluorodeoxyglucose avid on a subsequent positron emission tomography scan. There was a small-size pericardial effusion unchanged in size compared with a CT scan done 1 month prior at another hospital. The left ventricular ejection fraction was preserved and there were no signs of restriction or constriction on echocardiography. A transesophageal echocardiogram demonstrated the Watchman device seated in the LAA and a small 1-mm leak through the device (Figure 1B). Cardiac CT with contrast showed the occlusive device in the LAA with passage of contrast into the distal portion of the LAA confirming a small 1-mm peridevice leak, and without passage of contrast into the pericardial or pleural spaces (Figure 1C). The lack of passage of contrast into the pericardial and pleural spaces argued against direct communication between the LAA cavity and the pericardial or pleural space. The constellation of chest pain, stable pericardial effusion, recurrent pleural effusion, non-bloody nature of the pleural effusion, and the elevated hs-CRP were suggestive of an inflammatory process manifesting with pericarditis and recurrent left pleural effusion, likely precipitated by a micro-perforation of the fixation anchors during the Watchman placement.

MANAGEMENT

The patient was treated conservatively with nonsteroidal anti-inflammatory drugs (NSAIDs) and colchicine. She was not previously treated with anti-inflammatory medications after prior thoracenteses and during prior hospitalizations. Her symptoms of chest pain and shortness of breath gradually improved. Predischarge chest radiograph obtained 3 days following initiation of NSAIDs and colchicine showed left basilar atelectasis without reaccumulation of the left pleural effusion after chest tube removal. At discharge, she had significant improvement in her symptoms.

LEARNING OBJECTIVES

- The Watchman device is an LAA closure device that is increasingly used to prevent stroke among patients with atrial fibrillation. Complications associated with this device include pericardial effusion, tamponade, device erosion, and embolization. Although the safety profile of this device has improved with enhanced operator technical skills, it is important to recognize rare complications that may arise from the placement of this device. In this case report, we described the clinical presentation and management of recurrent pleural effusion and pericarditis following placement of the Watchman device.
- Pleural effusion is a rare complication of LAA closure with the Watchman device and can be the result of an inflammatory response due to intraprocedural pericardial injury.
- It is important to differentiate inflammation-related pleural effusion from bloody pleural effusion secondary to device erosion of the pericardial and pleural spaces.
- Conservative treatment with nonsteroidal anti-inflammatory drugs and colchicine can be successful in the treatment of post-Watchman pericarditis and exudative pleural effusion.

DISCUSSION

To the best of our knowledge, this is the first case of recurrent left pleural effusion after LAA occlusion with the Watchman device.

The Watchman device is an overall safe and effective device for LAA occlusion and protection of stroke among patients with atrial fibrillation (1). There were safety concerns with the initial experience with Watchman in the PROTECT-AF trial (WATCHMAN Left Atrial Appendage System for Embolic Protection in Patients With Atrial Fibrillation) given elevated risk of procedural complications, notably pericardial effusion and tamponade, device embolization, cardiac perforation, and air emboli (2); however, subsequent studies including the PREVAIL trial (Evaluation of the WATCHMAN Left Atrial Appendage [LAA] Closure Device in Patients With Atrial Fibrillation Versus Long-Term Warfarin Therapy) and prospective Watchman registries demonstrated an acceptable safety profile of the device with
improved operator technical experience (1,3). Although pleural effusion has not been previously reported following placement of Watchman, it has been described with the Lariat LAA ligation device, with an incidence of approximately 3% (4). The Lariat is an epicardial LAA occlusion device that requires both pericardial and transseptal access for percutaneous suture ligation of the appendage. Two types of pleural effusions were previously described with the Lariat: 1) exudative effusions thought to be related to local inflammation of the pleura adjacent to the pericardium covering the ligated necrotic LAA, often associated with pericarditis; and 2) transudative effusions possibly related to alteration of neuroendocrine regulation of fluid retention due to a decreased level of atrial natriuretic peptide that is usually produced by the LAA (5).

We hypothesize that the patient’s Watchman placement procedure was complicated by pericardial microperforation of the small fixation anchors, leading to a small amount of hemopericardium with subsequent self-sealing of the perforation. The pericardial injury and hemopericardium likely triggered an inflammatory response that manifested as pericarditis and recurrent exudative pleural effusion. The mechanism of the pleural effusion is either irritation of the left pleura by the adjacent inflamed pericardium or an immune-mediated inflammatory response similar to post-pericardiectomy syndrome and Dressler syndrome.

### FOLLOW-UP

The patient was discharged home on a 2-week course of NSAIDs and colchicine. A follow-up phone call at 3 weeks was performed and patient reported resolution of her symptoms while taking the anti-inflammatory medications; however, she started experiencing intermittent chest pain after completing her medical therapy. Repeat chest CT scans at 3 and 4 weeks showed unchanged small left pleural effusion and trace pericardial effusion. She was advised to take NSAIDs as needed, with relief of her chest pain. At 8 weeks, patient had complete resolution of her symptoms and she resumed her daily activities.

### CONCLUSIONS

We report the first case of recurrent left pleural effusion in the setting of pericarditis after placement of the Watchman device. Physicians should be aware of this rare complication and treat it conservatively with NSAIDs and colchicine before considering invasive treatments.

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KEY WORDS left atrial appendage closure, pericarditis, pleural effusion, post-pericardiectomy syndrome, Watchman
Catheter Ablation of Atrioventricular Block
From Diagnosis to Selection of Proper Treatment

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ABSTRACT

A 39-year-old man presented with recurrent syncope. A 12-lead electrocardiogram and a 24-h Holter recording demonstrated atypical persistent Mobitz type I and high-degree atrioventricular block, respectively. The functional nature of the atrioventricular block was confirmed by atropine challenge, exercise testing, and electrophysiological study. The patient was successfully treated with a cardioneuroablation procedure. (Level of Difficulty: Intermediate.)

A baseline electrocardiogram (ECG) showed an atypical persistent Mobitz type I atrioventricular (AV) block (AVB) and a narrow QRS complex (Figure 1A).

PAST MEDICAL HISTORY

A 39-year-old man with recurrent dizziness and syncope, but no other medical issues, was referred to the University of Health Sciences, Kocaeli Derince Training and Research Hospital, for permanent pacemaker implantation. Physical examination was completely normal except for an irregular heart rate.

Learning Objectives

To differentiate among subtypes of AVB by means of functional noninvasive and invasive testing.

To understand the role of CNA in the treatment of functional AVB.

A baseline electrocardiogram (ECG) showed an atypical persistent Mobitz type I atrioventricular (AV) block (AVB) and a narrow QRS complex (Figure 1A).

PAST MEDICAL HISTORY

The patient had dyspnea with onset of exercise that resolved after a few minutes. He reported frequent syncopal episodes with prodromal symptoms of nausea, a sensation of warmth followed by clammy skin, blurry vision and lightheadedness since adolescence that occurred with upright posture and light activity. Holter recordings revealed frequent intermittent high-degree AVB, reaching up to 4 consecutive blocked P waves (Figure 2).
DIFFERENTIAL DIAGNOSIS

The differential diagnosis included functional (vagal) AVB, intrinsic (structural) AVB, and extrinsic idiopathic AVB with accompanying vasovagal syncope.

INVESTIGATIONS

To determine the nature of the AVB, an atropine response test was conducted. During the test, a stepwise increase in sinus rate from 75 to 103 beats/min was noted, and partial resolution of AVB with a 240 ms PR interval was seen after administration of 2 mg of intravenous atropine (Figure 1B). Complete resolution of AVB was also noted during exercise stress testing (Figures 3A to 3F). At 20 min into a head-up tilt-table test, a typical cardioinhibitory response with an asystolic pause of 22 s was seen, resulting in loss of consciousness. An electrophysiological study revealed an HV interval of 46 ms and supra-Hisian atypical Mobitz type I AVB (Figure 4). Restoration of 1:1 AV conduction was achieved during overdrive atrial pacing (Figures 5A to 5C). During ablation on the RSGP, 1:1 AV conduction was achieved (Video 1). At the end of the procedure, intervals were as follows: PR interval, 198 ms; sinus node cycle length, 560 ms (Figures 7A and 7B); AH interval, 130 ms; and Wenckebach cycle length, 330 ms. When comparing the post-ablation ECG values (PR interval and sinus rate) with these values during the pre-operative atropine response, the results were consistent with complete vagal denervation.

DISCUSSION

Syncope secondary to AVB accounts for more than one-half of all arrhythmia-related syncopal episodes (1). Functional or vagal AVB is usually characterized by a sudden change from seemingly normal AV conduction to transient second- or third-degree AVB in response to vagal overactivity (2). Differentiation of vagal from intrinsic and extrinsic idiopathic AVB is important because no studies to date have shown a benefit of prophylactic pacemaker implantation in patients with vagal AVB (3).

Intrinsic AVB is usually initiated by premature extrasystoles, and sinus rate acceleration is observed during the block (4). Conversely, AVB is often accompanied by slowing of the sinus rate in functional AVB, and progressive PR interval prolongation preceding the AVB may also be seen. To differentiate intrinsic from functional types in cases of persistent AVB, atropine response testing may be used (5,6). In these studies, resolution of AVB during exercise, following atropine administration and during atrial pacing, were highly suggestive of functional AVB, as in the present case. Moreover, our patient had a normal HV interval at baseline and during atrial pacing, a finding supporting a functional mechanism. Extrinsic idiopathic AVB is characterized by recurrent syncope episodes without prodromal symptoms (7). In the present case, the prodromal symptoms were
FIGURE 1 Baseline and Atropine Challenge Electrocardiograms

(A) A 12-lead electrocardiogram at baseline with atypical persistent Mobitz type I atrioventricular block and a narrow QRS complex. Arrows show conducted P waves, curved red lines indicate PR intervals in conducted beats, and arrowheads point to blocked P waves.

(B) Response to 2 g intravenous atropine: normal 1:1 atrioventricular conduction is seen. Arrows show conducted P waves, curved red lines indicate PR intervals in conducted beats, and arrowheads point to blocked P waves.
consistent with an enhanced vagal response before the syncope.

The intrinsic cardiac autonomic nervous system forms a complex network composed of GPs, following relatively stable anatomic distribution. Experimental studies using a canine model have shown that the sinoatrial and AV nodes may be innervated by different GPs. AV nodal innervation is usually provided by GPs in the vicinity of the AV nodal region, whereas the RSGP predominantly affects the sinoatrial node. This association has not been confirmed in human subjects yet (8,9). In a recently published study, Bulava et al. (10) described a new technique for CNA to treat functional AVB, thereby avoiding ablation on the RSGP to prevent an increase in the heart rate. In the present case, however, despite sequential ablation of GPs on the left side, correction of functional AVB was not achieved until ablation was...
Baseline measurements at 100 mm/s paper speed using 3 surface electrocardiographic leads (I, II, and III) and 6 intracardiac electrograms positioned in the His bundle (ABL) and the coronary sinus (CS). The surface electrocardiogram shows atypical Mobitz type I atrioventricular block with irregular PR intervals. The intracardiac electrograms show supra-His block with a progressive increase in the AH interval (interval between the activation potential of the right atrium and the activation potential of the His bundle [H]) until the A potential is not followed by an H potential. Black arrows point to conducted P waves (P), and red lines indicate nonconducted beats. Note the irregular PR intervals before the nonconducted P-wave and prolongation of the PR interval after the blocked beat (from 255 to 333 ms).

The intracardiac electrograms (EGMs) were recorded in the right atrium (ABL), the coronary sinus (CS), and the left atrium (OPT). (A) Atrial pacing through the coronary sinus catheter at a cycle length of 600 ms resulting in 1:1 atrioventricular conduction with a 271-ms PR interval. (B) Atrial pacing at a cycle length of 500 ms causes a prolongation of the PR interval with continuation of 1:1 atrioventricular conduction. (C) 1:1 atrioventricular conduction with a 351-ms PR interval continued after cessation of pacing.
conducted on the RSGP. This case supports the theory that in some patients, a much wider ablation may be necessary to eliminate the vagal effect on the AV node. Although the clinical utility of a pre-procedural atropine challenge to detect vagal denervation was recently presented by our group, a more objective assessment of the GP ablation denervation effect may be performed using extracardiac vagal stimulation techniques (11,12).

CNA for intermittent high-degree AVB was first reported by Pachon et al. (13) in 2006. The clinical efficacy and reproducibility of this technique were later confirmed by several groups worldwide (5,6,13–15). According to the current bradycardia guidelines, the presence of symptoms is a major determinant of whether permanent pacing will be required in the setting of bradycardia associated with AVB (1). Functional AVB is usually transient and generally does not require cardiac pacing. However, in symptomatic patients, treatment may be warranted. CNA could be postulated as a better option for young patients with symptomatic functional AVB because the
current evidence shows excellent long-term outcomes and safe and reproducible results with this technique. Most importantly, CNA can eliminate the need for permanent pacing in this group of patients, thus avoiding a potential lifetime risk of pacemaker-related complications such as pace-mediated cardiomyopathy, lead malfunction, and device-related infections.

**FOLLOW-UP**

Repeated Holter recordings 1, 2, and 3 months after CNA revealed no further AVB episodes. Results of follow-up head-up tilt-table testing were completely normal at 1 and 3 months. No recurrent syncope was noted after a 3-month follow-up. Follow-up resting ECGs confirmed normal AV conduction (Figure 8).
CONCLUSIONS

CNA may be a valuable adjunctive therapy in patients with vagal AVB who cannot be adequately treated by conventional modalities and who refuse pacemaker implantation.

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**KEY WORDS** atrioventricular block, cardioneuroablation, catheter ablation, syncope, vagal denervation

**APPENDIX** For a supplemental video, please see the online version of this paper.
Cardioneuroablation for Treating AV Functional Block Without Pacemaker Implantation
Does it Really Work?*

José C. Pachon, MD, PhD, CCDS, Tomas G. Santillana, MD, Carlos T.C. Pachon, MD

The treatment of atrioventricular (AV) block by radiofrequency (RF) ablation without pacemaker implantation is intriguing. This is the challenge of a new procedure called cardioneuroablation (CNA) (1). It is obviously reserved for very well-selected cases; however, it is appealing that the ablation of some targets in the heart could treat bradyarrhythmias, eliminating symptoms and correcting the electrocardiogram, to the point of making pacemaker implantation unnecessary.

In this issue of JACC: Case Reports, Erkan et al. (2) present a case report in which CNA is used to treat symptomatic AV block. The authors obtained excellent results and achieved real benefit to the patient. It is noteworthy, however, that the AV block presented is more advanced than what is normally considered for CNA. In addition, this case had a mixed disorder, predominantly functional. Nevertheless, the clue to outcome was the partial response to atropine before the procedure, predicting that CNA could have a positive result and validating the indication. Due to the complexity of AV node innervation, the CNA technique for AV block is not yet fully defined, and many considerations and prudence are necessary. However, the current study is well founded in the literature. Nevertheless, the follow-up was short, and thus it is essential to continue to follow up this case to determine if a pacemaker was definitely avoided or postponed.

TECHNICAL ASPECTS

The CNA technique was created in the 1990s, aiming for vagal denervation by ablation to treat symptomatic functional bradyarrhythmias without pacemaker implantation, as well as vagal atrial fibrillation. The first cohort of 25 patients followed up post-CNA was published in 2005 (1), having neurocardiogenic syncope, sinus dysfunction, and 7 cases with symptomatic functional AV block. Soon after, in 2006, we published the first case report of high-grade AV block treated with CNA, gathering the first 8 cases, with a mean follow-up of 15.1 ± 4.9 months, in which CNA was used exclusively for treating functional AV block. In 4 patients, it was performed only by the right atrium. All patients became asymptomatic, but 1 case (12.5%) remained with occasional nocturnal Mobitz I AV block. In the others, CNA was performed by using a biatrial approach, and no AV block was observed.

CNA for the treatment of functional AV blocks is more challenging than that for other bradyarrhythmias and should be performed by using a biatrial approach; however, in addition to the technical details, it is essential to achieve total elimination of the AV block induced by left vagus nerve stimulation as the endpoint of the procedure (Figures 1 and 2).

LITERATURE

There are currently 388 publications on Google Scholar about CNA, with 15 controlled, prospective
studies totaling 501 patients and 1 systematic review (3). In addition, there are 9 case reports using CNA for treating AV block. In 41 cases, the primary indication was functional AV block. All the authors have been reporting high reproducibility, with very low complications and a mean recurrence of 9.2% with 19.8 months of follow-up. Nevertheless, CNA recurrences are a little more frequent than in neurocardiogenic syncope, ranging from 0% to 28.5%, depending on the author. This may be due to: 1) inadequate patient selection; 2) complexity of the anatomy and the innervation of the AV node; 3) different techniques and learning curves; and 4) lack of strict denervation control that can confirm the complete elimination of AV block induced by vagal effect at the end of the CNA (hard endpoint). Many cases with apparent immediate success may end with incomplete denervation, which can be completely reversed by natural reinnervation giving rise to recurrences.
**PATIENT SELECTION**

Before the procedure, we must be sure that the AV block is functional, that the conduction system is intact, and that there is an adequate response to atropine.

**COMPLEXITY OF AV NODE INNERVATION**

Due to the location, the AV node receives innervation from all ganglionic plexuses (GP), which makes it difficult to denervate. Furthermore, the procedure must be carefully performed to avoid AV node damage. Most of the innervation comes from GP2 located between the insertion of the right pulmonary veins (PVs), left atrial roof, and oval foramen, the so-called “P point” \(^{(4,5)}\), from GP3, between the coronary sinus ostium, inferior vena cava, left atrium wall, and from the GP4 close to the insertion of the left PV. This innervation distribution may differ significantly between patients. This feature determines whether the technique for vagal denervation of the AV node is more extensive and depends on ablations through the right atrium, left atrium, coronary sinus, inferior vena cava, interatrial septum, and even at the left PV insertion and Waterston’s groove. Thus, the ablation extension differs among patients and should be controlled by vagal stimulation to determine the appropriate CNA endpoint. In the current case report, Erkan et al. \(^{(2)}\) appropriately performed the biatrial approach. One of the common causes of recurrence is use of the simplified approach only through the right atrium, which can lead to insufficient denervation even with immediate apparent success.

**MAPPING THE NEURO-MYOCARDIAL INTERFACE**

This question is not yet fully defined. The spectral mapping of atrial fibrillation nests that gave origin to fractionation mapping in 2011 (Velocity-Precision, Abbott, Abbott Park, Illinois), associated with the anatomical approach, are highly appropriate \(^{(4)}\). In 14 studies with 460 patients, spectral mapping was performed in 35.7%, high-frequency stimulation in 42.8%, and an anatomical approach in 92.9% of cases; in 28.6%, the approach was anatomical only. Erkan et al. \(^{(2)}\) used atrial fibrillation nest ablation by mapping the fragmented potentials. As a rule, special care is needed, as the immediate result may not be sustained if enough denervation is not obtained in the initial procedure. Thus, stepwise functional verification during the procedure is essential.
CHECKING THE DENERVATION PROGRESS

In the original study, denervation was assessed by modification of the electrophysiological parameters, such as sinus node rate and the Wenckebach point increase, as well as by the loss of atropine response (1). However, due to the natural increase in sinus rate induced by CNA, the atropine test loss reliability. Furthermore, a sinus rate increase and 1:1 sinus AV conduction do not assure AV node denervation and the safety margin of AV conduction. Thus, we believe that CNA should be done under the strict control of vagal denervation by using extracardiac vagal stimulation (ECVS), which may be easily performed during the procedure (6) (Figures 1 and 2).

This approach consists of advancing a catheter through the internal jugular (Figure 1B) up to the jugular foramen at the cranium basis (6). In this location, due to the proximity to the vagus nerve (Figure 1C), ECVS is achieved even without direct contact with the nerve, using 50 Hz, 50 μs, with an amplitude of 1 V/kg of body weight up to a maximum of 70 V (Figure 1A). Typically, immediate asystole occurs due to the vagal effect (Figure 1D). However, considering that the AV node receives more innervation from the left vagus, while treating a functional AV block, we regularly perform stimulation of the left vagus during atrial pacing with 80 to 100 ppm, if necessary, to prevent bradycardia. This procedure aims to appropriately challenge the AV conduction (Figure 2B). The goal is to attain total disappearance of the vagal-induced AV block (Figure 2C) when complete AV node vagal denervation has been achieved.

Thus, the AV block induced by ECVS before or during CNA (Figure 2B) must be completely eliminated (Figure 2C). The hardest endpoint is the total elimination of vagal-induced AV block with or without atrial pacing. It is essential to achieve complete abolition of the vagal effect to guarantee a safety margin to counter the natural reinnervation that may affect the long-term result.

CONCLUSIONS

Several studies confirm that CNA can effectively treat functional AV blocks; however, a precise indication, a positive pre-CNA response to atropine, an accurate technique, and strict control of denervation during the procedure are essential.

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KEY WORDS: AV block, cardioneuroablation, pacemaker, RF ablation, syncope, vasovagal syncope.
Iron Deficiency Anemia-Induced Cardiomyopathy With Congestive Heart Failure
Reversible Cardiac Dysfunction Assessed by Multi-Imaging Modalities

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ABSTRACT

Iron deficiency anemia (IDA) can cause left ventricular (LV) dysfunction, causing heart failure. A 48-year-old woman with severe IDA developed congestive heart failure that was properly diagnosed, managed, and followed with multiple imaging modalities to explore potential mechanisms, highlighting the reversibility of LV function in unique cardiomyopathy. (Level of Difficulty: Intermediate.) (J Am Coll Cardiol Case Rep 2020;2:1806–11) © 2020 Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Severe iron deficiency anemia (IDA) has been reported to play a pivotal role in the development of heart failure (HF) through left ventricular (LV) dysfunction and myocardial damage, and substantial clinical benefits have been found as a result of iron deficiency treatment even without anemia (1). A remarkable feature of IDA-induced HF may be the reversibility of LV dysfunction with appropriate treatment. However, the pathogenesis of cardiomyopathy associated with IDA is unknown due to the limited number of affected patients. Here, we report an impressive case with severe IDA causing LV dysfunction and congestive HF, which was appropriately diagnosed and managed. The patient was followed up with multiple imaging modalities exploring the potential mechanisms of IDA-induced HF in terms of myocardial tissue characteristics and myocardial blood flow.

LEARNING OBJECTIVES

- IDA-induced cardiomyopathy can be characterized by severe chronic anemia, significant microvascular dysfunction, and high-output HF, which is reversible if treated properly.
- Multi-imaging modalities such as trans-thoracic echocardiography, CMR, coronary angiography with hemodynamics measurements, and cardiac positron emission tomography can improve accurate diagnosis and appropriate management.

HISTORY OF PRESENTATION

A 48-year-old woman presented with chronic leg edema and worsening exertional dyspnea. She also...
complained of menorrhagia with irregular periods more than 6 months ago. Vital sign measurements showed blood pressure of 107/48 mm Hg, heart rate of 81 beats/min, SpO₂ of 94% (room), and temperature of 36.9°C. Physical examination revealed marked pallor of the skin and conjunctiva, jugular vein distention, crackles in both lungs, rapid regular heart rhythm without any murmur, palpable spleen, and pitting edema of both lower extremities. Electrocardiogram showed normal sinus rhythm with horizontal ST depression in the limb leads (Figure 1A). Chest radiography revealed marked cardiomegaly and mild pulmonary congestion (Figure 1B). The initial hemoglobin level was 1.7 g/l, hematocrit level was 7.2%, and mean corpuscular volume was 55 fl. Iron parameters suggested severe IDA with an iron level of 8 μg/dl, total iron-binding capacity of 468 μg/dl, and ferritin level of 2 ng/ml. The rest of the blood test results and coagulation times, along with other laboratory tests, including clinical chemistry, renal, liver, and thyroid function, were normal except for an elevated level of N-terminal pro-B-type natriuretic peptide (NT-proBNP) (1,547 pg/ml). Stool guaiac tests were negative. The patient received three units of packed red blood cells in 4 days and was admitted for evaluation and treatment of severe IDA and HF.

PAST MEDICAL HISTORY

The patient’s medical history was unremarkable except for that she regularly smoked tobacco and consumed alcohol.

DIFFERENTIAL DIAGNOSES

The patient showed high-output HF with a high cardiac index and low systemic vascular resistance. Chronic high-output HF was explained by severe anemia after excluding other common causes, such as obesity, thyroid disease, arteriovenous shunts, and lung and liver diseases. By characterizing myocardial tissue, cardiac magnetic resonance (CMR) helped to distinguish secondary etiologies, such as myocarditis, amyloidosis, sarcoidosis, noncompaction cardiomyopathy, and dilated phase hypertrophic cardiomyopathy. 18F-fluorodeoxyglucose (18F-FDG) positron emission tomography/computed tomography (PET/CT) was useful in excluding myocarditis and sarcoidosis. Last, her benign clinical course, which was shortly controlled with iron replacement and transfusion of packed red blood cells, was more suggestive of HF due to severe IDA.

FIGURE 1 Electrocardiogram and Chest X-Ray on Admission and at 4-Month Follow-Up

Electrocardiogram on admission (A) and at the 4-month follow-up (C). Initial (B) and 4-month follow-up (D) chest x-rays.

ABBREVIATIONS AND ACRONYMS

18F-FDG = 18F-fluorodeoxyglucose
CMR = cardiac magnetic resonance
HF = heart failure
IDA = iron deficiency anemia
LV = left ventricular
NT-proBNP = N-terminal pro-B-type natriuretic peptide
PET/CT = positron emission tomography/computed tomography
INVESTIGATIONS

Initial transthoracic echocardiography showed a massively dilated LV chamber and left atrium with eccentric LV hypertrophy and trivial pericardial effusion (Figures 2A and 2B). On the seventh hospital day, coronary angiography (Figure 2C) revealed non-obstructive coronary arteries, and pressure studies were performed to assess LV end-diastolic pressure (9 mm Hg) and mean pulmonary capillary wedge pressures (9 mm Hg) with increased cardiac output at 9.0 l/min and systemic vascular resistance at 691 dynes/s/cm². Endomyocardial biopsy was avoided to prevent bleeding complications. CMR demonstrated biventricular dilatation and diffusely reduced LV wall motion with preserved wall thickness and absence of late gadolinium enhancement (Figures 3A to 3C). On day 12, PET/CT with 13N-ammonia (Figures 4A to 4C) demonstrated that ATP-induced stress myocardial blood flow was globally low with a considerable drop in the global coronary flow reserve to 1.70. Moreover, 18F-FDG-PET/CT detected abnormally high 18F-FDG uptake in the uterus with no metastases (Figure 5).

Finally, the patient was referred to our obstetrics and gynecology department where the solid mass in her uterus was diagnosed as endometrioid cancer on histology.

MANAGEMENT

Furosemide and enalapril were commenced, and the patient was gradually weaned from supplemental
oxygen. After the blood transfusion, she was treated with 7-day intravenous saccharated ferric oxide, followed by oral sulfate. At 3 weeks after discharge, she underwent a total hysterectomy with bilateral salpingo-oophorectomy at a university hospital; endometrial carcinoma was confirmed on pathological examination. At the 4-month follow-up visit, she was free of symptoms, where ST changes on electrocardiogram were normal with a normal cardiac silhouette on the chest radiograph (Figures 1C and 1D), serum hemoglobin, iron, ferritin, and NT-proBNP levels were within the normal range. Repeated CMR demonstrated that biventricular dilatation improved along with global LV wall motion, and late gadolinium enhancement was absent throughout the entire myocardium (Figures 3D to 3F). Perfusion PET/CT revealed a total recovery of global coronary flow reserve from 1.70 to 2.88 (Figures 4D to 4F).

**DISCUSSION**

We report a case of a middle-aged woman with chronic severe anemia and iron deficiency. We utilized novel imaging modalities to elucidate the potential mechanisms causing unique HF. Not only can progressive HF cause iron deficiency, but the converse can also occur. Iron deficiency can promote the remodeling of cardiomyocytes (2). Iron has roles beyond oxygen transport, including in the normal
**FIGURE 4** Perfusion Imaging and Myocardial Blood Flow Quantifications Using $^{13}$N-Ammonia PET in Acute Phase and at 4-Month Follow-Up

ATP-induced stress/rest $^{13}$N-ammonia positron emission tomography (PET) quantified the rest/stress myocardial blood flow (MBF) and coronary flow reserve (CFR) (A) with coronary territories (B) and myocardial perfusion imaging (MPI). (C) Both stress MBF and CFR were globally reduced at baseline and improved dramatically over the next 4 months to within normal ranges with the global CFR increasing from 1.70 to 2.88 (D and E). The MPI study demonstrated the involvement of the anterolateral and inferior walls with reversible myocardial ischemia, which significantly declined in size at follow-up (F). HLA = horizontal long-axis; LAD = left anterior descending; LCX = left circumflex; RCA = right coronary artery; SA = short-axis; VLA = vertical long-axis.

**FIGURE 5** Whole Body FDG-PET/CT Images

Fluorodeoxyglucose (FDG)-positron emission tomography (PET) (A) dedicated cardiac and whole-body imaging with a high-fat, low-carbohydrate, protein-preferred diet in the fasting state revealed no focal FDG uptake in the myocardium (B). Abnormally high FDG uptake was detected in the uterus with no metastatic sites (C).
activity of key enzymes of the citric acid cycle and reactive oxygen species scavenging enzymes. Decreased levels of reactive oxygen species scavenging enzymes in myocardial iron deficiency may intensify local oxidative stress, causing myocardial damage (3). As noted earlier, compromised oxygen delivery capacity may cause chronic tissue hypoxemia, which can lead to cardiomyocyte dysfunction. In our case, the initial perfusion PET/CT revealed significant microvascular dysfunction that may reflect global myocyte dysfunction. Moreover, IDA-induced cardiomyopathy had no association with myocardial inflammation, as shown by 18F-FDG-PET/CT.

A further remarkable aspect of the present case is the reversibility of IDA-induced cardiomyopathy confirmed with several imaging modalities. At the 4-month follow-up, when the patient was asymptomatic and her hemoglobin, iron, and NT-proBNP levels were normalized, we found remarkable improvements in cardiac function parameters assessed by transthoracic echocardiography, CMR, and perfusion PET/CT. This strongly suggests that IDA-induced cardiomyopathy may be almost completely reversible. However, it remains unclear whether complete normalization of LV function occurs in severe cases. Our present case showed that the LV remained slightly dilated after HF improvement, and these findings were in line with cardiac indexes measured by CMR imaging. Close observation to evaluate longer-term cardiac function and prognosis is warranted.

**FOLLOW-UP**

The patient continues to take enalapril. LV function by follow-up echocardiography and hemoglobin level are within normal ranges 12 months after hospitalization.

**CONCLUSIONS**

To our knowledge, this is the first case of severe IDA leading to LV dysfunction and congestive HF that was properly diagnosed, managed, and followed with multiple imaging modalities to explore the potential mechanisms. This case supports the reversibility of IDA-induced cardiomyopathy if treated properly, but further research is required to determine the level of improvement.

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**KEY WORDS** cardiac magnetic resonance, cardiomyopathy, iron deficiency anemia, positron emission tomography
Giant Calcified Left Circumflex Coronary Artery Aneurysm With Complex Coronary-to-Left Ventricular Communication

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ABSTRACT

A 64-year-old asymptomatic man had an incidental finding of a giant left circumflex artery (LCX) aneurysm, with the distal LCX draining into a confluence receiving terminal portions of all coronary arteries and communicating with the left ventricle through a transmural fistulous tract. We believe that this is the first case reported with such a complex LCX abnormality. (Level of Difficulty: Beginner.) (J Am Coll Cardiol Case Rep 2020;2:1812–7) Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 64-year-old asymptomatic man underwent a computed tomography (CT) scan of the abdomen and pelvis for evaluation of hematuria. The scan revealed an incidental finding of left circumflex artery (LCX) aneurysm. His physical examination was unremarkable for any acute or chronic cardiovascular findings. Upon admission, his vital signs were as follows: blood pressure, 136/89 mm Hg; pulse, 74 beats/min and regular; respiratory rate, 18 breaths/min; temperature, 98.1°F; and pulse oximetry, 97% on room air.

PAST MEDICAL HISTORY

The patient had history of well-controlled hypertension and no other modifiable or nonmodifiable risk factors or clinical markers of coronary artery disease.

DIFFERENTIAL DIAGNOSIS

Because of the incidental CT findings in this asymptomatic patient, the possibility of congenital versus acquired coronary aneurysm was raised. Given that the patient had not undergone any coronary interventions, the possibility of past iatrogenic causes or coronary manipulation was excluded.

INVESTIGATIONS

Subsequent coronary CT angiography (CTA) showed a giant (3.7-cm), calcified proximal LCX aneurysm with a small thromboatheroma (Figure 1). An additional smaller, noncalcified distal LCX aneurysm was present. Furthermore, the distal LCX drained into a confluent structure receiving terminal por-
tions of the remainder of the coronary arteries (Figures 2 and 3). This confluence communicated with the left ventricle (LV) through a moderate-caliber transmural fistulous tract (Figures 3 and 4). The left anterior descending artery was markedly enlarged and tortuous proximally, and it appeared to drain into the arterial confluence distally. The right coronary artery was dominant, with a normal caliber, and it terminated distally into the confluence. Increased trabeculation was present in the LV at the anterolateral segment. A transthoracic echocardiogram (Figure 5) showed normal left ventricular and right ventricular systolic function without any wall motion abnormalities or valvular heart disease. Cardiac magnetic resonance revealed normal resting myocardial perfusion, normal biventricular function, a normal pulmonary-to-systemic flow ratio, and no evidence of delayed gadolinium enhancement (Figures 6A and 6B). An exercise single-photon emission computed tomography myocardial perfusion imaging study demonstrated no inducible ischemia, with normal left ventricular ejection fraction. We could not identify any additional congenital abnormalities or signs of infection or vasculitis in the past medical history or during the index evaluation.

**LEARNING OBJECTIVES**

- LCX aneurysm is an extremely rare clinical condition. Careful evaluation of the coronary anatomy is needed to identify any additional coronary anomalies in these patients. Our case represents a unique anatomy, with a giant LCX aneurysm and the distal LCX draining into a confluence receiving terminal portions of all coronary arteries and communicating with the LV through a transmural fistulous tract.
- Complex coronary anomalies require in-depth evaluation, including multimodality imaging to assess the patients for presence of myocardial ischemia and significant left-to-right shunt. Cardiac CTA is a very helpful diagnostic tool in establishing definitive anatomy in these cases.
- The treatment should be individualized on the basis of the patients’ symptoms, objective prediction of risk (presence of ischemia, progression of the lesion), and the presence of associated coronary and cardiac anomalies.
- With a careful work-up and follow-up, this coronary anomaly may have a benign short-term clinical outcome.

**MANAGEMENT**

The patient was managed conservatively using dual antiplatelet therapy (aspirin and clopidogrel) and a statin because coronary artery thrombosis and progressive stenosis within the aneurysm may cause myocardial ischemia, which increases the risk of myocardial infarction and sudden cardiac death in these patients. The patient took warfarin for a month, but it was stopped because of hematuria and hematospermia. He also underwent yearly coronary CTA for surveillance without significant change in the size of the aneurysm, and he has remained without cardiac complications to date for a total of 3 years. At present, nonradiation modalities such as cardiac magnetic resonance are not beneficial in this case because of the need in a 3-dimensional imaging modality with excellent all-axis spatial resolution (isometric voxels) for depiction of such a complex coronary anatomy.

**DISCUSSION**

The incidence of coronary artery aneurysms is 0.02% to 0.04%, and these aneurysms are usually seen in the right coronary artery. To our knowledge, there has been no case reported of a patient with an LCX aneurysm with coronary-to-LV communication. Careful evaluation of the coronary anatomy is needed to identify any additional coronary anomalies in these patients.

**ABBREVIATIONS AND ACRONYMS**

- CT = computed tomography
- CTA = computed tomography angiogram
- LCX = left circumflex artery
- LV = left ventricle

A 3-dimensional (3D) volume-rendered (VR) image of the lateral cardiac surface that shows a giant left circumflex (LCX) coronary artery aneurysm, left anterior descending artery (LAD), obtuse marginal branch, and part of the left ventricular (LV) transmural fistula. CTA = computed tomography angiography; LA = left atrium.
These 3D VR images of the inferior and lateral cardiac surface show a giant LCX coronary artery aneurysm, an LV transmural fistula, and confluence receiving terminal portions of all the coronary arteries. Multiplanar reconstruction (MPR) images show a giant left circumflex coronary artery aneurysm and confluence receiving terminal portions of all the coronary arteries. RA = right atrium; RV = right ventricle; other abbreviations as in Figure 1.

These 3D VR images of the apical and lateral cardiac surface show the LAD, LCX, LV transmural fistula, and confluence receiving terminal portions of all the coronary arteries. MPR images show an LV transmural fistula and confluence receiving terminal portions of all the coronary arteries. Abbreviations as in Figures 1 and 2.
These 3D VR and MPR images show a giant LCX coronary artery aneurysm, an LV transmural fistula, and the LCX. Abbreviations as in Figure 1.

This apical 4-chamber echocardiogram shows normal-size cardiac chambers, normal valves, and a calcified LCX aneurysm. Abbreviations as in Figures 1 and 2.
aneurysm communicating with a distal coronary arterial confluence, and this confluence further connected to the LV through a fistulous track. LCX aneurysms with fistulous communication have rarely been reported; among the reported aneurysms, most communicated with the coronary sinus (1). Only 1 case report described LCX aneurysm with a fistulous communication to the LV myocardium through several small vessels (2).

Coronary artery aneurysms may represent a potentially life-threatening condition with important complications including thrombosis or rupture. Of note, our patient was asymptomatic. The available treatment options for coronary artery aneurysm with fistula are surgical or endovascular interventions (1). However, treatment depends on the complexity of the anomalous anatomy. Furthermore, the follow-up duration and treatment with surgical or endovascular interventions in asymptomatic patients are unknown. A systematic approach with possible multicenter registries, development of a specific diagnostic approach, and prognostic estimates in patients with this complex anatomy, requires further research.

**FOLLOW-UP**

The patient underwent yearly coronary CTA for surveillance without significant change in the size of the LCX aneurysm, and he has remained without cardiac complications to date for a total of 3 years.

**CONCLUSIONS**

LCX aneurysm is an extremely rare clinical condition. Careful assessment of the coronary anatomy is needed to identify any additional coronary anomalies in these patients. Evaluation of such a unique anomaly as giant LCX aneurysm combined with distal LCX draining into a confluence receiving terminal portions of all coronary arteries and communicating with left ventricle through a transmural fistulous tract requires implementation of advanced 3-dimensional imaging methods.

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KEY WORDS coronary artery aneurysm, coronary fistula, left ventricular fistula
VIEWPOINT

JACC: Case Reports
Reflections From 1 Year on Social Media

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“What we measure shapes what we collectively strive to pursue- and what we pursue determines what we measure”

—Commission on the Measurement of Economic Performance and Social Progress (1)

In the last decade, the rapid growth of SoMe has transformed the way that clinical knowledge is disseminated and accessed (2). An increasing amount of scientific discourse is happening virtually and in real-time, where new clinical and research output is being shared, learned, reviewed, and acclaimed by the social networks formed by cardiovascular professionals on various SoMe platforms. A novel approach to understanding the extent of this ongoing virtual dialogue on published data is to measure it with emerging metrics like the altmetric attention score (AAS), which assesses the immediate impact of new papers on the readership (3). Since its inception in June 2019, JACC: Case Reports has embraced the importance of increased educational opportunities for the readership by harnessing the novel aspects of these SoMe platforms.

The purpose of this viewpoint is to describe the journey of JACC: Case Reports in the digital world with focus on readership and engagement through SoMe metrics.

ALTMETRIC ATTENTION SCORE

Altmetrics is a catch-all term for contemporary metrics that were developed to complement traditional citation metrics, such as impact factor (4). AAS (identified by a colorful “donut” with a central number on peer-reviewed journal papers) is derived from a weighted count of the amount of attention a paper receives in multiple sources with default weightings, including earned media/news outlets, blogs, policy documents, patents, Wikipedia, Twitter, peer review journals, Weibo, Google+, F1000, syllabi, LinkedIn, Facebook, Reddit, Pinterest, Q&A, and YouTube (5). In 2018, the AAS covered 64 million mentions of 9 million academic outputs. The highest attributable score comes from media/news outlets (especially those with the greatest distribution), and the lowest score is assigned to YouTube.

The burning question of the relationship of the AAS to citations has been raised before. Although previous studies did not show correlation of AAS with a higher number of citations, some developing evidence shows that promotion of a paper on SoMe may be linked to paper downloads and citations (6–9). For a case report journal, however, one may argue that the overall readership may be a stronger gauge of engagement, due to the fact that case reports may rarely get cited. One of the most effective ways to evaluate the overall readership impact is by measuring the paper downloads. Although downloads are dependent on many factors, such as clinical utility of the case report and interest of the reader,
one of the ways to make the cases visible is via sharing it in academic social networks on SoMe (10). The easiest way to generate a higher AAS for a case report is to share it on Twitter or other SoMe platforms, as citing a case report in news, blogs, policy documents, patents, Wikipedia, and such other components of the AAS would be rare.

**SoMe EFFORTS OF JACC: CASE REPORTS**

*JACC: Case Reports* is an open access journal that launched in June 2019 under the leadership of Editor-in-Chief Dr. Julia Grapsa. The vision for this exclusively open access and online journal was to develop an interactive and engaging forum that serves to promote cardiovascular disease education, complement clinical guidelines, involve all members of cardiovascular care team, and serve as a publication vehicle and mentorship opportunity for early career and fellow-in-training cardiovascular professionals (11). *JACC: Case Reports* is not limited to clinical case reports, but also publishes the following paper types:

- Clinical Case Series
- Global Health Reports
- Heart Care Team/Multidisciplinary Team Live
- ECG Challenges
- Imaging Vignettes
- Voices in Cardiology, including a Fellow-in-Training corner
- A Continuing Medical Education Case of the Month

In addition, *JACC: Case Reports* has had multiple minifocus issues covering a wide variety of topics, including interventional complications and their management, valvular heart disease, women’s cardiovascular disease, electrophysiology and pacing, cardiomyopathies and genetic counseling, and heart failure. In the unprecedented coronavirus disease 2019 pandemic era, *JACC: Case Reports* has expeditiously published timely and highly educational content, reacquainting cardiologists with critical care skills and highlighting the different presentations of a novel global disease.

*JACC: Case Reports* has placed significant emphasis on the role of SoMe in expanding readership and driving engagement by recruiting a multidisciplinary, highly accomplished, and enthusiastic SoMe team to its editorial board. Since its launch, *JACC: Case Reports* has had a globally expansive SoMe footprint. The main focus of the SoMe team is to create and share scientific journal-related content on SoMe platforms (mainly Twitter and Facebook) to promote medical education, encourage advocacy, and drive engagement. The virtual nature of the SoMe platforms lends itself well with intellectually stimulating peer-reviewed high-quality case reports with predominantly pictorial content (8). These posts include high-quality illustrative figures and videos, interactive patient cases, quizzes, polls, video case presentations, and video interviews. The hashtag #JACCCaseReports is utilized to label all SoMe posts related to *JACC: Case Reports*. The content is shared by the *JACC* journals’ formal SoMe accounts in addition to individual *JACC* editors’ accounts (Figure 1).

As *JACC: Case Reports* recently completed its first year of publication in June 2020, a palpable requisite for the SoMe team along with the editorial board is to measure the impact of collaborative SoMe efforts on overall readership of the papers and further understand the interests of the readers. In this viewpoint, we have looked at these questions using the metrics for papers published in *JACC: Case Reports*. Given that the AAS gives a credible view of the SoMe impact on initial readership of a paper, we examined the top 100 papers ranked by AAS, obtained its components to see the role of SoMe in the AAS (retrieved on April 1, 2020), and evaluated paper downloads (PDF and HTML downloads) through May 2020. We further categorized the papers by paper type as described by *JACC: Case Reports*. Voices of cardiology with strong clinical viewpoint were given a separate category of “viewpoint.”

When studying the impact of the SoMe team in disseminating the journal’s content, AAS applies certain modifiers to offset potential bias set by active “sharing” of papers by the editorial board (12). These modifiers sometimes take into account the connection between the “tweeter”/author of SoMe post and the journal being promoted for a given paper. For example, a tweet by a member of an editorial board or a SoMe member of *JACC: Case Reports* may not be counted in terms of AAS as compared with a post shared by an independent “tweeter.” This is an important consideration when analyzing the overall AAS associated with a published paper.

**JACC: CASE REPORTS: Top AAS PAPERS**

We analyzed the top 100 papers by AAS score published in *JACC: Case Reports* from June 2019 to May 2020. Median AAS score for these papers was 18 (interquartile range [IQR]: 13.0 to 43.5), while median for downloads was 1,136 (IQR: 759 to 2,807) (Table 1). Among the top 100 papers, 65% were case reports and 5% were clinical case series and editorial comments. In total, 16% of the papers were Voices in Cardiology
Median Twitter component (retweets) for top 100 was 35 (IQR: 26.5 to 78.0). Apart from Twitter, contributions of any other AAS components were minimal; hence, the median value for the composite of other components could not be calculated. Of the top 10 AAS papers, however, 4 were from the category “Voices in Cardiology,” whereas Clinical Cases, Viewpoint, and Editorial were represented equally (2 each) (Table 2). While examining the association between AAS score and download, we found a moderate association between AAS score and Twitter component of AAS score, with downloads for top 100 papers categorized by highest altmetric until May 2020 (Figures 2A and 2B).

**CARDIOTWITTER, SoMe ENGAGEMENT, AND ALTMETRIC**

This analysis of top 100 AAS papers illustrates that for *JACC: Case Reports*, AAS is mostly dependent on sharing the content on Twitter with minimal contribution from other AAS components. Second, categories like Voices in Cardiology and Clinical Viewpoints, which are published infrequently, generate substantial interest on SoMe. Finally, AAS and Twitter mentions moderately predict downloads. This analysis suggests that the concerted efforts of SoMe team has undoubtedly increased the visibility of *JACC: Case Reports* and amplified its impact on the educational and advocacy front along with possibly advancing the readership, as evident by a moderate correlation between AAS score and overall downloads (Figure 1). Based on this analysis, however, it would be difficult to ascertain how case reports generate interest in the virtual world. Similar to other research output, case report dissemination on SoMe may be dependent on sharing by SoMe influencers with large

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**TABLE 1** Analysis of Top 100 Papers Published in JACC: Case Reports by Paper Types and Median Downloads, AAS, and Twitter Mentions From June 2019 to May 2020

| Paper Type                  | Total Numbers | Median Downloads | Median AAS | Median Twitter Retweets |
|-----------------------------|---------------|------------------|------------|-------------------------|
| Clinical Cases              | 65            | 929              | 17         | 30                      |
| Clinical Case Series        | 5             | 1,389            | 27         | 38                      |
| Global Health Reports       | 1             | 1,564            | 12         | 21                      |
| Heart Care Team             | 2             | 14,706           | 67         | 32                      |
| Voices in Cardiology        | 16            | 2,564            | 58.5       | 151.5                   |
| Viewpoint                   | 4             | 997              | 41.5       | 69                      |
| Editorial Comment           | 5             | 984              | 71         | 133                     |
| Da Vinci Corner             | 2             | 664              | 40.5       | 73                      |
| All papers                  | 100           | 1,136            | 18         | 35                      |

Papers published in *JACC: Case Reports* were selected by Top 100 altmetric attention score (AAS) and further categorized by paper type. For each paper type, median downloads, AAS, and its components were collected by May 15, 2020.
follower base, use of images, central illustrations, and other engagement tools like polls or quizzes or podcasts (3,8).

The cardiovascular community on Twitter has grown substantially in the last few years and is comprised of thought leaders, academicians, practicing cardiologists, as well as fellows-in-training. With exponential growth in the number of scientific journals, we live in an information paradox where we have access to excessive amounts of information. SoMe acts as a prism that sheds new light to clinically relevant and essential topics (3). SoMe
used strategically allows for bite-sized discussions facilitated by content dissemination that may allow for the generation of future hypotheses and increase overall scientific collaborations and, ultimately, scientific output (13,14). Although case reports are seldom cited, educational discussion around high-quality peer-reviewed case reports are exceedingly engaging on SoMe, particularly among fellows-in-training and early career professionals. The cardiovascular professional often takes advantage of a virtually integrated yet worldwide network to showcase their clinical work and research output with an additional (intentional or unintentional) benefit of enhancing the AAS. Although acknowledgment of published work by colleagues (via retweet) in virtual communities may be instant and easy, its causation remains complex to fully understand (15). SoMe communities, including Cardiotwitter, depend on social connection and generation of overall social capital by gaining trust of colleagues. Amplification of the content by SoMe users (via like and retweet) may reflect their true learning interest within the subject and their expertise, but it may also be a result of the secondary motivation of boosting the social bond with the posting individual. Paper downloads, however, are largely free of such biases, and moderate correlation of AAS score with paper downloads, as shown for these top 100 AAS papers, may indicate organic paper “traffic” generated via SoMe dissemination.

There are several limitations to the AAS score. Although sharing of the paper by the journal or by editorial board gets less attention than someone unrelated to the journal or editorial board, a fundamental concern with AAS is the process of data collection, management, and update of SoMe impact to generate this score. Also, AAS does not provide information about the quality of the paper; on the contrary, criticism/negative attention is also counted as “attention” (16).

Nonetheless, the infinite potential of SoMe for dissemination of scientific knowledge is undeniable with free, around-the-clock, immediate communication that happens without boundaries of academic hierarchies, with democratization of voices and unmoderated communication. AAS is a mere reflection of this ongoing dialogue. Its prospective to become a potential quality metric from an attention metric keeps scientific journals interested in exploring the ways to make the content easily readable and accessible to the SoMe users. No doubt the techniques for sharing and using clinical cases on SoMe have changed the local trends in clinical practice in United States (#radialfirst, #dontdistethesis) (8). Yet, the true clinical impact of sharing relevant peer-reviewed cases online on betterment of patient care or on scientific progress by hypotheses-generation within virtual academic communities will be difficult to gauge.

**CONCLUSIONS**

This is the first analysis from a case report journal that details the spectrum of AAS and its high impact on the cardiovascular community. As SoMe evolves from vanguard to bedrock of medical publishing, peer-reviewed high-quality papers from *JACC: Case Reports* will continue to aim to engage the readership through novel means to advance cardiovascular care.

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**KEY WORDS** altmetric score, Cardiotwitter, case reports, social media, Twitter
An 89-year-old woman presented at the emergency department with the following paroxysmal events that started 6 days earlier and occurred approximately 3 times a day. First, she experienced visual and auditory complex hallucinations. Subsequently, she would scream or yell out a short phrase and shake her arms for several seconds, followed by loss of consciousness for 5 to 10 s. When unconscious, her eyes were open and her gaze was directed upward. Afterward, she would immediately be oriented and could provide details of the experienced hallucinations. The events occurred in both upright and supine position. She did not bite her tongue nor was she incontinent during these events. A video recording of an event is provided in the online supplement (Video 1).

**PAST MEDICAL HISTORY**

Her medical history consisted of transient ischemic attacks due to right-sided carotid artery stenosis (treated conservatively at the patient’s request), deep vein thrombosis, paroxysmal atrial fibrillation for which she used warfarin and digoxin, chronic obstructive pulmonary disease, moderate left ventricular hypertrophy with a left ventricular ejection fraction of 50%, moderate aortic valve stenosis (mean...
pressure gradient 28 mm Hg), and moderate to severe mitral and tricuspid valve insufficiency. She had no prior psychiatric disorders.

DIFFERENTIAL DIAGNOSIS

Epileptic seizure, cardiac syncope, reflex syncope, delirium.

INVESTIGATIONS

On admission, her blood pressure was 150/104 mm Hg and she had a regular pulse of 58 beats/min. Upon cardiac auscultation, she had a mild crescendo-decrescendo systolic murmur at the right upper sternal border and moderate holosystolic murmur at the apex. Basic neurological examination was unremarkable. Laboratory examinations and chest X-ray were normal. The electrocardiogram (ECG) showed normal sinus rhythm, normal conduction, and signs of left ventricular hypertrophy with strain. Cranial computed tomography showed an old silent brain infarct in the left basal ganglia. During simultaneous video, ECG, and electroencephalogram (EEG) recording of an event, the ECG recording showed an atrioventricular block followed by an asystole. After several seconds of asystole, symptoms of hallucinations, screaming, and shaking began, followed by loss of consciousness (Figure 1, Video 2). The EEG showed diffuse high-amplitude slow activity after which the EEG became isoelectric, a typical EEG pattern for syncope (1).

MANAGEMENT

Our patient was diagnosed with syncope due to intrinsic paroxysmal atrioventricular block. After pacemaker implantation (dual chamber pacemaker), the events no longer occurred.

DISCUSSION

Transient loss of consciousness is a commonly encountered symptom and may pose a clinical dilemma, as the underlying condition can be difficult to establish. The major causes are epileptic seizure,
cardiac syncope, reflex syncope, and syncope due to orthostatic hypotension (1). An important first step is to attempt to distinguish epilepsy from syncope. Signs suggestive of epilepsy are a lateral tongue bite, postictal confusion, lateral head deviation, unusual posturing, preceding aura, or focal neurological manifestations (e.g., aphasia, unilateral limb shaking) (2,3). However, discriminating epilepsy from syncope based on symptoms alone can be difficult, as there is substantial overlap in symptomatology. During any type of syncope, individuals can exhibit either loss of muscle tone, myoclonic jerks, or stiffening of arms and legs (4,5). A video analysis of 42 cases of induced syncope showed that myoclonus occurred in 90% of cases (although myoclonus never preceded the loss of consciousness), 79% had other motor activity (e.g., lateral head deviation, automatisms, head raising, or sitting up), 40% vocalized (moaning sounds), and visual and auditory hallucinations occurred in 60% of individuals (6). Importantly, patients assigned these hallucinations to the period of unconsciousness or during the period afterward, but did not experience them before losing consciousness (6,7). Prodromal hallucinations would normally be suggestive for epilepsy (8,9). Therefore, a diagnosis of epilepsy was initially suspected in our patient, which was the reason for performing the ECG-EEG recording that established the diagnosis of cardiac syncope instead. Thus, the limb shaking, vocalizations, and hallucinations in our patient were caused by cerebral hypoperfusion. Of note, cardiac arrhythmia can occur secondary to an epileptic seizure (10), but this was ruled out with the EEG registration and further substantiated by the fact that no more events occurred after pacemaker implantation. In accordance with established guidelines, the initial diagnostic workup of a patient suspected of syncope should include a careful history taking, including the situation in which syncope occurs, the nature and duration of prodromal symptoms, bystander observations, post-event symptoms, prior medical history and medication use, and family history with emphasis on syncope and sudden unexplained death (10). In the current case, high-risk features suggesting cardiac syncope were the presence of structural heart disease, a short history of syncope, age >60 years, very short prodromes, and syncope occurring in supine position (10). A diagnosis of reflex syncope should be considered in case of more prolonged prodromal signs, absence of a prior history of heart disease, younger age, specific triggers (e.g., dehydration, pain, stress, micturition) and a long history of syncope (10). Syncope occurring in the setting of positional change (supine to sitting, sitting to standing) is suggestive of orthostatic hypotension. Recommended physical examination in case of syncope includes blood pressure and heart rate and rhythm, testing for orthostatic hypotension if the patient’s history is compatible with this condition, cardiac auscultation, and a basic neurological examination. Performing an ECG in syncope is recommended and performing targeted blood tests (e.g., to exclude anemia) is reasonable, whereas routine and comprehensive laboratory testing is not considered useful (10). After pacemaker implantation, the events no longer occurred.

CONCLUSIONS

Patient-reported information combined with interictal examinations are paramount to diagnosing the cause of transient loss of consciousness, but are not always sufficient. Our case demonstrates that, although prodromal hallucinations are usually indicative of epilepsy, this phenomenon also can occur in cardiac syncope. In atypical and recurrent cases, registration of an event is essential and should be pursued.

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**KEY WORDS** cardiac syncope, epilepsy, hallucinations, syncope, transient loss of consciousness

**APPENDIX** For supplemental videos, please see the online version of this paper.
Over the past 6 months, the coronavirus disease-2019 (COVID-19) pandemic has transformed cardiovascular medical education in numerous ways (1). In the early stages of the U.S. pandemic, cardiovascular fellowship training programs were challenged with redesigning educational curricula to accommodate remote learning, balancing trainee well-being and safety with in-person clinical care opportunities, decreased procedural volumes, redeployment of fellows to noncardiology services, rapid uptake of telemedicine, and protecting the emotional and psychological health of trainees (2,3). As we transition into a new academic year, training programs are approaching a new and daunting challenge posed by COVID-19: virtual fellowship recruitment.

Due to physical distancing mandates and institutional travel prohibitions, the Coalition for Physician Accountability’s Work Group on Medical Students in the Class of 2021 Moving Across Institutions for Post Graduate Training recommends that all fellowship programs should commit to online interviews and virtual visits for all applicants (4). The Association of American Medical Colleges (AAMC) has developed a unidirectional Video Interview Tool for Admissions for the medical school application process this year (5); however, we anticipate that cardiology fellowship programs will conduct live, bidirectional interviews using online video conferencing software. Although there are AAMC recommendations for conducting medical school and residency interviews virtually (6), there is no cardiology fellowship program-specific guidance available, and few cardiology programs have prior experience with virtual interviewing.

General cardiology fellowship applicants, who are largely current internal medicine residents, have also been significantly affected by the COVID-19 pandemic, and many of these consequences directly impact their fellowship candidacies (Table 1). Fellowship program leaders face related challenges in navigating this virtual recruitment season but should also remain mindful of applicants’ circumstances (Table 1). Here, we outline the common challenges that general cardiology fellowship applicants and programs will face during the 2020 recruitment season with a focus on the virtual interview, and we offer strategies to support and guide trainees and program leaders through the virtual interview process.

**PRE-INTERVIEW**

For the July 2020 cycle, the Electronic Residency Application Service (ERAS) delayed the date that fellowship programs may begin reviewing applications by 1 month, moving from a traditional mid-July date to August 12, 2020 (7). The National Resident Matching Program (NRMP) did not similarly postpone the deadlines for rank list submissions (November 18,
2020) or Fellowship Match (December 2, 2020) to preserve the matching options for individuals who may cross apply in different medical specialties or couples match. Because of the limitations of the virtual interview process (Table 1), applicants will likely need to intensify their pre-interview research about programs and perform their inquiries over a shortened timeline. Program timelines for reviewing and inviting applicants has been truncated by a month, and this may impact previously standardized applicant review processes. Discussion surrounding application and interview inflation, as a consequence of uncertainty and the decreased financial and time costs of virtual interviews, is speculative, but these metrics should be tracked.

**APPLICANTS.** Resources for information on fellowship programs include program Web sites and official social media profiles and accounts. Applicants should pay particular attention to programs’ distinctive characteristics, including level of exposure to advanced cardiovascular diagnostics and therapeutics during general fellowship, subspecialty fellowship opportunities, support for advanced degree and research training programs, and professional development opportunities (e.g., national meeting attendance policies, education stipends, availability of board review resources). Applicants should seek information on the post-fellowship positions of graduates from programs of interest. Institutional graduate medical education Web sites should house information on maternity and paternity leave policies; leaves of absence related to pregnancy or personal or family illnesses; childcare and spousal support; moonlighting; and health insurance, retirement, and disability benefits, and applicants should be prepared to discuss their questions regarding these topics on the interview day. For additional information on program geographic locations, applicants can review official tourism and institutional Web sites about living in the city/town of interest.

Regarding interview scheduling, applicants should reply to program coordinator/administrator communications promptly and refrain from overlapping interviews with other work-related commitments (e.g., on-call shifts) or other interviews. Applicants should allow flexibility in scheduling to accommodate unforeseen circumstances.

**INTERVIEWERS.** As programs build their resource collections, they may consider incorporating innovative strategies to showcase important training experiences that may be hidden during a virtual interview. For example, programs could include pictures and/or videos of cardiac catheterization and noninvasive imaging laboratories with virtual tours or clips taken by fellows. In addition to lists of subspecialty training opportunities, profiles and expertise of key teaching and research faculty could be shared on Web sites and on social media platforms.

Before the interview, programs and interviewers should extend clear expectations for the virtual interview format. Instructions should include how to log in and out of virtual interview rooms, what to do if appointments finish early or run over time, and contingency plans for audiovisual problems and Internet service disruptions. Phone numbers should be exchanged between applicants and interviewers as a

| TABLE 1 Challenges Facing Applicants and Programs During the 2020 Cardiovascular Disease Fellowship Recruitment Season |
|---|
| **Applicants** | **Programs** |
| Lack of exposure to cardiology due to less elective time and redeployment to COVID-19 care | Changes to application review processes |
| Fewer scholarship opportunities due to cessation of research activities and professional meeting cancellations during COVID-19 | Minimal guidance from governing bodies available on evaluating applicants under current circumstances |
| Less exposure to potential mentors and sponsors | Uncertainty regarding number of applications that will be received |
| Uncertainty in pursuing extended training in economic recession | Adopting new bidirectional virtual interviewing platforms |
| Uncertainty of COVID-19’s future impacts on cardiovascular fellowship training | Updating and accommodating production costs for Web sites, videos, social media profiles |
| Policy changes for immigrant physicians on temporary employment or exchange visitor visas | Incorporation of bias elimination strategies in application review and interviews |
| Managing short- and long-term “Zoom fatigue” | Mitigation of applicant and interviewer “Zoom fatigue” |
| **Abbreviated interview season** | Shorter timelines for reviewing applications and conducting interviews |
| **Virtual recruitment** | **Virtual recruitment** |
| Navigating various program interview practices and expectations | Orienting faculty to new interviewing practices and expectations |
| Lack of training in best practices for virtual interviewing | Lack of training in best practices for virtual interviewing |
| Inability to visit hospital campuses and see geographic locations of programs | Creating new opportunities for informal engagement among applicants, fellows, and faculty |
| Inability of partners and families to assess new locations | Conveying program culture through virtual platform |
| Decreased exposure to fellows, faculty, program culture | Managing pre- and post-interview contact with applicants |

As programs build their resource collections, they may consider incorporating innovative strategies to showcase important training experiences that may be hidden during a virtual interview. For example, programs could include pictures and/or videos of cardiac catheterization and noninvasive imaging laboratories with virtual tours or clips taken by fellows. In addition to lists of subspecialty training opportunities, profiles and expertise of key teaching and research faculty could be shared on Web sites and on social media platforms.
failsafe in case of technical issues. Interviewers should strive to know the applicants’ profiles well and avoid spending interview time asking questions that can be easily verified by reviewing the application. We suspect that because applicants will not be able to meet faculty in person or visit the facilities or the city/town, they will likely have more questions than to which interviewers may be accustomed and may need more time in the interview to discuss these aspects of the training program. Interviewers should avoid scheduling interviews to overlap with clinical or administrative obligations.

**INTERVIEW DAY**

It remains unclear if programs will choose to structure interview days with all interviews being held over the same day for each applicant or if they will trial interviews with sessions spread over multiple days. These variations may lead to a change in the atmosphere of an “interview day.”

**APPLICANTS.** Expectations for applicants to wear professional attire will remain unchanged. Applicants should plan to hold virtual interviews in a comfortable, distraction-free setting with adequate lighting and be mindful of their backgrounds and environments while on camera. For sound quality, applicants may choose to use separate wireless headphones and/or microphones instead of built-ins. Residency programs should consider establishing reserved space for applicants from which to conduct interviews if they are unable to identify appropriate spaces within the home.

During the interview, applicants should look into the camera lens as much as possible and try to maintain “eye contact” with interviewers. Interviewees may need to exaggerate nonverbal communication in order to convey enthusiasm across a video platform. Applicants should expect time for pauses due to connectivity delays and should consider having a rehearsed system for note taking while maintaining engagement during the interview. Adhering to interview schedules is important, and applicants should keep program coordinators’ contact information readily available in case of issues.

Engagement with fellows should be a primary goal for the interview day. Potential conversation topics include fellows’ training experiences, academic interests and accomplishments, fellowship camaraderie, mentorship and sponsorship from faculty,
advanced training opportunities, and the impacts of COVID-19 on their education. Advanced training opportunities about which applicants are encouraged to inquire include exposure to advanced imaging tools, mechanical support strategies, interventional and structural devices, and specialized electrophysiological procedures.

**INTERVIEWERS.** Although the video platform can facilitate a casual atmosphere, interviewers should strive to maintain a professional appearance and setting and refrain from commenting on applicants’ backgrounds or locations. Interviewers should ensure that the applicant can be seen and heard and vice versa at the start and should reserve extra time for questions. As a departure from the traditional interview, faculty should offer additional personal knowledge to the applicant such as their interactions with fellows, information on the career trajectories of program graduates, and experiences of living in the particular geographic location.

**PROGRAM DIRECTORS.** Program directors will likely provide program overviews in various ways; for example, large group meetings at the beginning or end of interview days, one-on-one meetings, prerecorded videos. To facilitate applicants’ understanding of the large amount of information that will need to be shared, program directors may consider providing them with supplemental digital or printed content with detailed information on specific aspects of their program. Program directors should share their mission statements, visions for program and trainee culture, and offer supportive visuals of day-to-day life as a fellow. They also should be forthcoming about the past, present, and anticipated impacts of COVID-19 on fellowship training. Specifically related to the COVID-19 era, program directors may address prescription of physical distancing protocols for fellows’ clinical duties in the catheterization or noninvasive laboratories. They also may discuss any current or anticipated alterations to traditional training timelines. Perhaps to a greater degree than in the past, program directors could consider connecting applicants with potential faculty mentors and fellows after the interview day to facilitate acceptable post-interview conversation.

**POST-INTERVIEW**

Historically, post-interview contact with applicants has been limited due to governing body regulations that protect applicants and programs (8). Applicants can consider contacting program directors to express interest in the program if they are truly considering ranking it highly. To mitigate bias and promote equity, second-look requests by external applicants and in-person interview requests from internal candidates should be strongly discouraged. Program directors and interviewers should be prepared for increased post-interview contact given the potential for unanswered questions from applicants. As in past years, programs may offer opportunities for additional and optional contact with faculty in the applicant’s area of interest.

**CONCLUSIONS**

Navigating the virtual interview platform during this unprecedented time may be challenging to both applicants and program leaderships, but we must all remember that our shared goals of selecting and nurturing the next generation of cardiovascular clinicians remain the same. Communicating clear instructions and contingency plans will be instrumental in planning and executing successful virtual interviews (Figure 1). The 2020 fellowship recruitment season will provide many opportunities to experiment and innovate, and we are confident that valuable and enduring lessons in cardiovascular graduate medical education will be learned in the process.

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KEY WORDS awareness, cardiovascular disease, coronavirus, education, lifestyle
We are all alerted and emotionally exhausted from the COVID-19 pandemic, without any doubt. When I saw my family after 7 months, I felt very emotional, as it was the first time in my life that it had taken so long to see them. Sometimes, I was in doubt whether I would ever see them again.

Here in the United Kingdom, we were hit hard by the COVID-19 pandemic, during which time we encountered not only the victims but also the “hidden” victims, those patients who will need long-term support or those caregivers who have been in such emotional distress that it will be difficult for them to completely recover. I feel for my friends and colleagues in the United States and other countries, which are still undergoing the peak of the pandemic.

We encountered extremely sick patients, young patients, with no comorbidities who spent many months in the intensive care unit, dependent on mechanical support. Patients who died without their families, families who would send voice messages to very sick patients in the hope that they would understand while being intubated.

Without a doubt, the debilitating situation of the COVID-19 pandemic has brought many teaching points into our everyday life:

1. Humility: As Dr. Valentin Fuster and Mrs. Justine Varieur Turco wrote in a wonderful Editor’s Page at the beginning of the pandemic, “We should never forget the importance of being humble and sagacious, both individually and as a society. We are already witnessing glimmers of hope” (1). Indeed, now we are humble in front of what is happening—we are waiting patiently for treatments, for the upcoming vaccine, for hope. From the very beginning, we in the health care field have recognized the value in sticking together through all of this. I have heard much constructive criticism related to which countries were well prepared for the pandemic with earlier lockdowns, which is tremendously important for the efficient management of COVID-19. However, we should not get into the habit of inefficient, unconstructive criticism wherein political leaders identify others’ performance as better or oftentimes worse. We are all in this together.

2. Teamwork: respecting each other: In the United Kingdom, our hospital was one of the main COVID centers in London and, gradually, we are returning to normal practice seeing patients who have been afraid to come to the hospital, even those who may have been very sick. Again, we should not forget what happened a few months ago. It is important to respect each other and all our work together that it took to respond to the daily demands but also to prepare for a potential second wave. A part of mutual respect is also the spread of false information from people who have a poor understanding of COVID-19. We hear a few voices, some of which are unfortunately from my home country, protesting against wearing masks or social distancing. Please trust the scientific evidence, trust what experts say: wear a mask.

3. Empathy: We have changed as caregivers. We took a step back, we reflected. Now we have started behaving differently, maybe engaging more with patients, having more empathy for patients and their families. Patients are fearful of the coronavirus, and it is now proven that many preferred to have a heart attack at home rather than coming to the hospital. Families are worried as well, rightly so. Therefore, it is another teachable moment for us that we need to be more understanding, to have more empathy. Last week, I asked a colleague cardiothoracic surgeon: “When you speak to a patient, are you thinking of them as if that patient was your mother or your father?” Without much thought, he immediately replied “of course,
always.” During COVID-19, his ethos and the way he cared about his patients made me a better clinician and human being. We learn from each other. COVID-19 has shaped us as doctors, human beings, colleagues.

4. **Mindfulness**: When I go to the hospital, I try to live every moment as if I am discovering the place from scratch: I notice the surroundings, I notice my colleagues, the balance between them; every day is a teachable moment for me. During the COVID-19 pandemic, many colleagues with whom we worked closely died unexpectedly, which was a shock for many of us. It makes us think that we redefined our priorities, and this respect for each other will maintain. We should remain grateful to be alive, grateful to wake up every morning.

5. **Equality**: As I mentioned previously, we are all in this together: the #Blacklivesmatter movement has been so powerful in the middle of the pandemic, and it needs to be a part of our everyday life. More recently, the #womenempoweringwomen movement has arisen. We are in the middle of 2020, we have been through the first wave of a pandemic, we have witnessed many deaths around us. If anything, this disease has reinforced for us that we are all equal, regardless of color, sex, age. We need to have institutional policies that reflect those beliefs.

Now more than ever, we have an opportunity to reform as a society in the same way as we reformed as clinicians and human beings. I strongly feel that we should never forget what happened in the past 6 months, and we need to continue to support each other. “And one has to understand that braveness is not the absence of fear but rather the strength to keep on going forward despite the fear.”—Paulo Coelho

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Letters

Takotsubo Syndrome Associated With COVID-19
And the InterTAK Diagnosis Score?

Since the onset of the coronavirus disease-2019 (COVID-19) pandemic, several case series have noted cardiac arrhythmias, cardiomyopathy, acute coronary syndromes, and cardiac arrest in patients with COVID-19 infection (1). Several acute respiratory infections may result in activation of coagulation pathways, proinflammatory effects, and endothelial cell dysfunction. The mechanisms of myocardial injury in COVID-19 infection remain to be understood, however (1,2). The article by Minhas et al. (3) in JACC: Case Reports describes 1 of the first cases of Takotsubo syndrome (TTS) triggered by COVID-19 infection. The InterTAK Diagnostic Score was developed by the International Takotsubo Registry to assess the likelihood of a TTS diagnosis. The scoring criteria are based on clinical and electrocardiographic features to predict the probability of TTS and to distinguish TTS from acute coronary syndromes. Patients with 30 score points have a predicted probability of 90% of TTS. TTS case descriptions in patients with COVID-19 did not refer to the InterTAK score to evaluate the probability of TTS in these patients (4,5). It would be important to know whether InterTAK scoring could also contribute to distinguishing electrocardiographic abnormalities in patients with COVID-19 and whether the InterTAK score would allow clinicians to predict the likelihood of TTS during the COVID-19 outbreak.

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REPLY: Takotsubo Syndrome Associated With COVID 19
And the InterTAK Diagnosis Score?

We would like to thank Dr. Reper and colleagues for their comments on our recent case report describing a patient with Takotsubo syndrome (TTS) triggered by coronavirus disease-2019 (COVID-19) (1), as well as for suggesting the use of the InterTAK Diagnostic Score for patients with TTS in this setting. For our patient, the calculated InterTAK score is 50 (25 points for female sex, 13 points for physical trigger, and 12 points for the absence of ST-segment depression). As stated in the original description of this score, “patients with 50 points have a probability of 18%...of suffering from TTS” (2). Although the InterTAK score may be helpful in other patients with TTS, in the case of our patient the score as calculated did not strongly support or refute a diagnosis of TTS. For our patient, the classic imaging pattern on the initial echocardiogram and the reversibility seen on a subsequent echocardiogram were more consistent with TTS, thus leading to our diagnosis. We acknowledge that this is
the case of only 1 patient, and the utility of the InterTAK score should be assessed in a larger cohort of patients with possible TTS triggered by COVID-19 to understand the use of this score in this setting more clearly.

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