Absent Right Coronary Artery in an Active Young Female

Wanda Koester Qualters, MS[1], Sarah E. Chase, BS[1]

PATIENT BACKGROUND

JB is a 22-year-old white female with a history of back pain and 2 microdiscectomies who was a 3-sport athlete in high school and played Division III softball during college. Since graduating college, she has been working as an inpatient nurse. In April 2020, her nursing unit was transitioned to care for COVID-19 patients. Approximately two months later, in June 2020, JB noted her exercise tolerance had declined to a level far below what she had been able to achieve just a few months prior. During that time, her running pace and distance had gradually decreased due to fatigue and occasional chest discomfort. Later that year, she began experiencing sensations of her heart "beating really hard" during aerobic exercise training. She noted heart rates (HRs) of 190 to 200 b·min^{-1} on several different occasions. These HRs were alarming to her because just 10 months earlier she had been running 5 miles without undue fatigue at HR of 130 to 140 b·min^{-1}.

Upon consultation with a cardiologist in November 2020, a 24-hour Holter monitor and transthoracic echocardiogram were ordered and were interpreted as normal. However, during a subsequent treadmill exercise stress test where she completed 10 minutes and 15 seconds on the Bruce protocol and achieved a peak HR of 176 b·min^{-1} (88% of age-predicted maximum HR), JB experienced test-limiting chest discomfort and exhibited 0.5 mm upsloping ST segment depression in leads II, III, a VF, and V4-V6. A coronary computed tomography (CT) scan was ordered and she was advised to continue regular exercise and follow a heart-healthy diet.

Results of her coronary CT revealed a congenital absence of the right coronary artery (RCA) ostium and proximal RCA (Figure 1). The left circumflex artery continued into the right atrioventricular groove to supply the RCA myocardial tissue and ended before reaching the right coronary sinus. The CT findings were confirmed during cardiac catheterization and no flow-limiting lesions were identified. Her cardiologist prescribed ranolazine 500 mg twice daily and referred her to cardiac rehabilitation (CR) since she continued to experience chest discomfort during exertion.

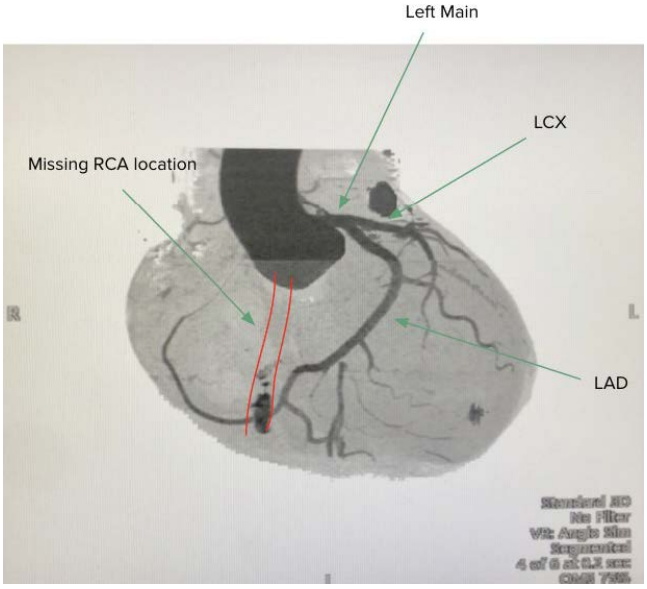

FIGURE 1. Coronary computed tomography (CT) scan.

EPIDEMIOLOGY

The prevalence of coronary artery anomalies has been estimated in the range of 0.2% to 1.3% among patients undergoing cardiac catheterization (1,2). Twenty percent of these anomalies results in myocardial infarction, and in rare instances may cause sudden death (2,3). Findings of a single coronary artery (SCA) arising from the aortic root to supply the entire heart are extremely rare, reportedly occurring in <0.02% of cardiac catheterizations (4–9). Fewer than 80

[1]Division of Cardiovascular Medicine, Henry Ford Health System, Detroit, MI 48202 USA

Address for correspondence: Wanda Koester Qualters, MS, Preventive Cardiology, Division of Cardiovascular Medicine, Henry Ford Medical Group, 6525 2nd Avenue, Detroit, MI 48202; e-mail: wqualte1@hfhs.org.

Conflicts of Interest and Source of Funding: None

cases of absent RCA have been reported in the literature (4–9). A PubMed search for cases of SCA between January 2011 and December 2020 resulted in 38 cases of an absent RCA reported in 34 articles (8). Among these cases, 16 were women with a mean age of 50 years at the time of diagnosis.

ETIOLOGY

Congenital coronary artery abnormalities are typically identified incidentally in conjunction with other types of congenital heart disease. Congenital absence of a coronary artery is presumed to be caused during the embryonic period, either by lack of development (agenesis) or occlusion of an artery during development, but the exact pathogenic mechanisms for this are unknown (6,8–10). When individuals with this congenital heart condition present with symptoms, responsible mechanisms have been suggested to include a coronary steal phenomenon (i.e., shunting of blood from high to low resistant coronary circulation) or slow controlled ischemia caused by a long travel distance of coronary flow (6,8,11). In cases where there is an absent RCA, the left system becomes super-dominant and compensation occurs via the distal circumflex artery which follows the right atrioventricular groove to supply the RCA territory. A SCA has been suggested to contribute to symptoms of ischemia because a relatively small proximal vessel may either be diseased or may cause reductions in overall coronary blood flow, which could enhance the hemodynamic significance of distal coronary artery lesions (12). However, estimates suggest only 15% of patients with a SCA experience ischemia due to the direct consequence of the anomaly (11).

CLINICAL MANIFESTATIONS AND DIAGNOSIS

Few individuals with a coronary artery anomaly are symptomatic, and most coronary artery anomalies are identified incidentally during coronary angiography or during autopsy despite this type of heart condition being present at birth (2,3). Individuals with the congenital absence of a coronary artery often present with varying and non-specific clinical and electrocardiographic manifestations. Some experience angina pectoris, dyspnea, palpitations, or myocardial infarction. Others experience syncope, ventricular tachycardia, and/or sudden cardiac death (SCD), particularly with exertion (2,3).

Coronary artery anomalies are suggested to be the second most common cause of SCD in young athletes, behind hypertrophic cardiomyopathy (2). Patients with coronary anomalies commonly present with atypical chest pain or other wide-ranging manifestations, particularly in the absence of obstructive coronary artery disease (3–6). Atrial fibrillation, mitral regurgitation, cardiomyopathy, heart failure, and pulmonary embolism have also been reported as clinical signs of a SCA (5,11).

Coronary angiography is considered the gold standard for diagnosing the congenital absence of coronary arteries. Noninvasive tests such as CT angiography are also helpful in that the left and right coronary arteries can be evaluated simultaneously without the large amount of contrast medium that may be required during coronary angiography. Images provided by CT angiography scanning also provide excellent views of the ostium and take-off angle of aberrant vessels, which may play an important role in evaluating the potential for SCD (13,14).

TREATMENT

Treatment for the congenital absence of coronary arteries depends on the presence or absence of coronary atherosclerosis. When a patient is diagnosed with acute myocardial infarction and critical flow-limiting coronary artery lesions are identified, coronary revascularization is typically performed. When coronary atherosclerosis is not present or coronary stenosis is not severe, conservative medical treatment in the form of antiplatelets, anticoagulants, coronary artery dilators, anti-hypertensive therapy and lipid-lowering agents can be employed (6,13).

EXERCISE IMPLICATIONS

While most coronary artery anomalies are considered benign (2,5), a SCA may be more serious (1). However, there is a paucity of contemporary data to support general agreement on either the safety or specific dangers of exercise in those with a SCA. The American Heart Association and American College of Cardiology provide expert guidance in a 2015 statement on how to best determine the appropriateness of exercise associated with some coronary artery anomalies, but recommendations specifically regarding exercise in those with a SCA are not provided (15).

The available evidence on exercise participation in those with congenital coronary artery abnormalities is largely specific to those whose condition has an anomalous origin. Examples include a coronary artery that arises from the pulmonary artery, the origin of the left main coronary artery arising from the right sinus of Valsalva, and the RCA arising from the left coronary sinus. Individuals who are at highest risk for SCD typically demonstrate a dominant artery with an anomalous origin that perfuses a large area of myocardium (14). Therefore, because coronary artery anomalies are estimated to account for approximately 17% of SCD among competitive athletes (15), prior to engaging in sport competition or other forms of high-level exercise training it is important that individuals with known congenital heart disease have their specific type of coronary anomaly identified and receive medical clearance from a physician, preferably a cardiologist specializing in congenital heart diseases.

CASE – CLINICAL COURSE

Following her cardiac evaluations, JB was referred to outpatient cardiac rehabilitation (CR) in February 2021 with a diagnosis of stable angina. She admitted to the CR staff, “all my life I have felt out of shape; I could never catch my breath,” and stated she consistently felt very fatigued following exercise. These feelings of exercise intolerance typically remained limited to exercise participation and had not limited her ability to work as an inpatient nurse.

On her first day of CR, JB experienced chest discomfort at a HR of 124 b·min^{-1} while walking on the treadmill. The CR staff terminated her exercise at that time and her symptoms resolved following a short break. It was then recommended that she exercise on the seated stepper where she achieved a HR of 129 b·min^{-1}without experiencing further chest discomfort. At her second CR session, the CR staff implemented a longer warm up to help facilitate maximal vasodilation, and recommended she begin her aerobic exercise sessions using a nonweight-bearing modality. These combined training modifications allowed her to exercise without chest discomfort for that CR session.

During CR sessions 3 and 4, JB experienced symptoms associated with inappropriate HR responses. As she moved from a seated piece of exercise equipment to a standing position, she experienced a pronounced increase in HR of approximately 15 to 30 b·min^{-1}and complained of lightheadedness during each episode. A cardiopulmonary exercise test (CPET) had been ordered as part of her referral to CR, which she performed after visit number 5. During her cardiopulmonary exercise test she experienced test-limiting chest discomfort and exhibited 0.5 to 1.0 mm upsloping ST segment depression in leads II, III, and aVF at a HR of 165 b·min^{-1}. These signs and symptoms were interpreted as her ischemic threshold and she was instructed to not allow her exercise training HR to exceed 155 b·min^{-1}. No other abnormal cardiovascular responses were observed during her CPET, including no reproduction of an inappropriate HR response when she moved from a seated to standing position immediately prior to beginning the test.

During most CR sessions JB avoided treadmill walking because of her extensive history of back pain, which was unrelated to her cardiac condition. Typical exercise modalities used during CR sessions were the elliptical trainer and/or seated stepper performed for a total of 30 to 40 minutes. However, despite discontinuing ranolazine, adding metoprolol succinate ER (12.5 mg daily), and following her recommended exercise HR limits suggested at her CPET, she continued to experience episodic chest discomfort, even at HRs as low as 125 b·min^{-1} (Table 1). After nearly 3 months in CR and completing 29 sessions, her cardiologist decided to add isosorbide mononitrate 30 mg daily to her medication

TABLE 1. Cardiac rehabilitation overview.

Visit Number	Max Exercise HR (b·min^{-1})	Symptoms During Exercise	Notes
1	129 on SS	Chest discomfort on TM	Onset of chest discomfort at 124 bpm. Exercise modes: TM and SS
2	130	None	Added longer warm-up and started with nonweight-bearing exercise. Modes: TM/SS.
3	125	Lightheaded with HR spike	HR spiked to 152 bpm when moving from SS to TM
4	125	Lightheaded with HR spike	HR spiked to 140 b·min^{-1} when moving from SS to TM
5	121	None	Modes: TM/SS
…	…	…	CPET performed between visit 5 and 6. Recommended HR <155 b·min^{-1} with exercise
6	150 on E	Chest discomfort on E	Modes: E and SS
7	125	None	Stopped ranolazine. Started metoprolol succinate ER 12.5 mg daily. Modes: TM/SS
8	160 on E	Chest discomfort on E	Modes: E/SS
9	125 on TM	Chest discomfort on TM	Modes: TM/SS
10–25	127–157	None	No chest discomfort. Modes: TM/SS/E
26	150 on E	Chest discomfort on E	Modes: E/SS
27	135	None	Intermittent chest discomfort earlier in the day prior to session Modes: E/SS
28	138	None	Absent for 10 days prior to this visit, during which she had intermittent chest discomfort. Modes E/SS
29	144	None	Started isosorbide mononitrate 30 mg daily. Modes E/SS
30	153	None	States no chest discomfort since starting isosorbide mononitrate (9 days prior) Modes E/SS.
31	152	None	Modes: TM/SS
32	136	None	Modes: E/SS
33	127	None	Modes: E/SS
34	144	None	Modes: E/SS

CPET = cardiopulmonary exercise test; E = elliptical; HR = heart rate; SS = seated stepper; TM = treadmill

regimen. Following this medication update her symptoms improved almost immediately, and she completed the remainder of her CR sessions while remaining asymptomatic.

Despite achieving symptom-free exercise training by the time she completed her CR program, at 3 months post-CR JB experienced a noteworthy episode of "crushing" chest discomfort while sitting in her car, ultimately leading her to visit the local emergency department. This recurrence of her chest discomfort prompted her to seek a second opinion. A positron emission tomography (PET) stress test was ordered and was interpreted as negative for ischemia. Her new cardiologist then decided to discontinue the isosorbide mononitrate while concurrently increasing her daily metoprolol dose, which resulted in improved symptom severity and frequency during both rest and exertion.

DISCUSSION

Participation in CR resulted in improvement of JB's cardiorespiratory fitness by approximately 1 metabolic equivalent of task (MET). However, despite this along with improved symptom severity during CR, JB felt no lasting improvement in her symptoms after graduating the program as she continued to experience exertional and nonexertional chest discomfort and dyspnea.

Much remains unanswered regarding the sudden persistence and episodic nature of the signs and symptoms experienced by JB. In the absence of coronary artery ischemia, it is possible other factors might be responsible for her chest discomfort. The most likely cause could be attributable to coronary artery spasm which may result in the symptoms experienced, but this is also something that can typically be well-managed pharmacologically with agents such as calcium channel blockers and/or long-acting nitrates (16). Because JB had resting HRs in the mid-40s, taking multiple rate-limiting pharmacologic agents were not an appropriate option. Therefore, the selection of a long-acting nitrate (isosorbide mononitrate) in combination with metoprolol was attempted and temporarily successful in managing her chest discomfort, but ultimately it was determined that discontinuing the isosorbide mononitrate and increasing the metoprolol succinate ER dose offered JB the best symptom management.

This case study demonstrates that not everything is known about exercise in those with SCA. This young woman had a successful career as a collegiate athlete, yet 4 years later began struggling to consistently complete bouts of moderate exercise without experiencing chest discomfort or other symptoms. This case is also a reminder that CR programs routinely receive referrals for patients exhibiting unique or unpredictable signs and symptoms that may require many modifications to the exercise prescription before enrollees begin to experience benefits. Therefore, it is important that CR staff are not only knowledgeable about the general principles of exercise prescription, but they demonstrate strong teamwork and communication skills, critical thinking, and the creativity required to continually personalize the exercise prescription to fit the needs of enrollees throughout the entire CR program. While managing JB's care, the CR staff effectively communicated with other providers in her care team and successfully instituted multiple modifications to the exercise prescription, including a longer warm-up, changing modalities during warm up, changing modalities and the order of use during aerobic exercise, and altering workloads in response to her symptoms. Since graduating from CR and receiving the second opinion and modification to her pharmacologic regimen, JB is currently able to consistently jog at a low-to-moderate intensity pace and has completed a 5k without experiencing chest discomfort.

REFERENCES

1. Yamanaka O, Hobbs RE. Coronary artery anomalies in 126,595 patients undergoing coronary arteriography. Cathet Cardiovasc Diagn. 1990;21:28–40.
2. Yildiz A, Okcun B, Peker T, Arslan C, Olcay A, Vatan MB. Prevalence of coronary artery anomalies in 12,457 adult patients who underwent coronary angiography. Clin Cardiol. 2010;33(12):E60–4.
3. Elbadawi A, Baig B, Elgendy IY, Alotaki E, Mohamed AH, Barssoum K, Fries D, Khan M, Khouzam RN. Single coronary artery anomaly: a case report and review of literature. Cardiol Ther. 2018;7:119–23.
4. Akcay A, Tuncer C, Batyraliev T, Gokee M, Eryonucu B, Koroglu S, Yilmaz, R. Isolated single coronary artery. A series of 10 cases. Circ J. 2008;72:1254–8.
5. Iftikhar I, Rehman AU, Khan HS. A single coronary artery with an absent right coronary and a superdominant left circumflex giving off a branch supplying the right coronary artery territory. J Coll Physicians Surg Pak. 2019;29(Suppl 2):S80–2.
6. Chen A, Yan JH, Han X, Adhikari BK, Zhang J, Zhang Y, Sun J, Wang Y. Congenital absence of the right coronary artery with acute myocardial infarction: report of two cases and review of the literature. Int J Med Res. 2020;48(12):1–10.
7. Desmet W, Vanhaecke J, Vrolix M, Van De Werf F, Piessens J, Willems J, De Geest H. Isolated single coronary artery: a review of 50 000 consecutive coronary angiographies. Eur Heart J. 1992;13:1637–40.
8. Oh S, Kim JH, Kim MC, Hong YJ, Ahn Y, Jeong MH. Posterior myocardial infarction caused by superdominant circumflex occlusion over an absent right coronary artery: case report and review of literature. Medicine. 2021;100: 27(e26604).
9. Yan GW, Bhetuwal A, Yang GQ, Fu QS, Hu N, Zhao LW, Chen H, Fan XP, Yan J, Zeng H, Zhou Q. Congenital absence of the right coronary artery: a case report and literature review. Medicine. 2018;97:12(e0187).
10. Mahapatro AK, Patro ASK, Sujatha V, Sinha SC. Isolated single coronary artery presenting as acute coronary syndrome: case report and review. Int J Angiol. 2014;23:143–6.
11. Choi HY, Kim JW, Moon JM, Kim YJ, Choic CU, Lim HE, Kim EJ, Rha SW, Park CG, Seo HS, Oh DJ. Unusual dominant course of left circumflex coronary artery to right coronary

artery territory with absent right coronary artery. J Cardiol. 2010;55:117–9.
12. Lipton MJ, Barry WH, Obrez I, Silverman JF, Wexler L. Isolated single coronary artery: diagnosis, angiographic classification, and clinical significance. Radiology. 1979;130: 39–47.
13. Taylor AJ, Rogan KM, Virmani R. Sudden cardiac death associated with isolated congenital coronary artery anomalies. J Am Coll Cardiol. 1992;20(3):640–7.
14. 14. Liberthson RR. Sudden death from cardiac causes in children and young adults. N Engl J Med. 1996;334(16):1039–44.
15. Van hare GF, Ackerman MJ, Evangelista JK, Kovcs RJ, Myerburg RJ, Shafer KM, Warnes CA, Washington RL. Eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities: task force 4: congenital heart disease: a scientific statement from the American Heart Association and American College of Cardiology. J Am Coll Cardiol. 2015;66(21): 2372–84.
16. Slavich M, Suleman Patel R. Coronary artery spasm: current knowledge and residual uncertainties. Int J Cardiol Heart Vasc. 2016;10:47–53.