GREGORY W. RUTECKI, MD, Section Editor

Felix Wangmang, MD, PharmD
Department of Medicine, Cedars-Sinai Medical Center, Los Angeles, CA

Achilles Aiken, MD
Department of Cardiology, Smidt Heart Institute, Cedars-Sinai Medical Center, Los Angeles, CA

Kuang-Yuh Chyu, MD, PhD
Professor, Department of Cardiology, Smidt Heart Institute, Cedars-Sinai Medical Center, Los Angeles, CA

Shortness of breath in a 52-year-old man with HIV and severe mitral regurgitation

A 52-year-old man presented to the emergency department with 3 weeks of acute on chronic dyspnea on exertion with progression to dyspnea at rest and associated orthopnea. He reported having experienced dyspnea with exertion for years, which he had attributed to work-related fatigue and which had not caused significant exercise limitations. However, starting 2 years earlier, his dyspnea progressively worsened without any acute triggers. At that time, he began using more pillows for orthopnea.

He denied recent travels, fevers, chills, diarrhea, chest pain, weight gain or loss, and sick contacts. His medical history included a history of well-controlled human immunodeficiency virus (HIV) infection, heart failure with preserved ejection fraction, and mitral valve prolapse with severe mitral regurgitation. He denied using tobacco or alcohol, currently using illicit drugs, or making any dietary changes. He reported briefly using methamphetamine 2 years ago, and he has since stopped. He endorsed taking his prescribed medications, which included emtricitabine-tenofovir alafenamide, dolutegravir, and furosemide 40 mg twice daily.

Three weeks before his current presentation, the patient was admitted to an outside hospital for an acute heart failure exacerbation. At that time, he had dyspnea on exertion after walking 1 flight of stairs and after walking to his car from his door. While hospitalized, he underwent aggressive diuresis, which resulted in only mild improvement in his symptoms. Therefore, he was referred for consideration for percutaneous mitral valve repair.

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EVALUATION ON ADMISSION

On admission, the patient was afebrile, and his blood pressure was 109/73 mm Hg, heart rate 103 beats per minute, and respiratory rate 22 breaths per minute with an oxygen saturation of 99% on room air. He was alert and oriented to person, place, and time. His lungs were clear to auscultation bilaterally. Heart rate and rhythm were regular, with a III/VI holosystolic murmur at the apex. No jugular venous distention or peripheral edema was noted.

Laboratory testing

Notable results of blood testing were as follows:

- B-type natriuretic peptide 2,122 pg/mL (reference range < 100)
- Troponin I 0.02 ng/mL (< 0.04)
- HIV RNA copies undetectable (undetectable)
- HIV antigen-antibody test reactive (negative)
- Sodium 140 mmol/L (136–145)
- Bicarbonate 23 mmol/L (22–31)
- Creatinine 0.9 mg/dL (0.72–1.25)
- Hemoglobin 15.8 g/dL (13.0–17.0)
- Hematocrit 46.7% (37.5–49.9)
- Platelet count 225 × 10^9/L (150–450)
- Aspartate aminotransferase 85 U/L (5–34)
- Alanine aminotransferase 84 U/L (0–55)
- Direct bilirubin 0.3 mg/dL (0–0.5)
- Total bilirubin 1.2 mg/dL (0.2–1.2)
- Albumin 4.3 g/dL (3.5–5.2).

Chest radiography and electrocardiography

A chest radiograph showed an enlarged cardiac silhouette without signs of pulmonary edema (**Figure 1**). An electrocardiogram (ECG) showed sinus tachycardia

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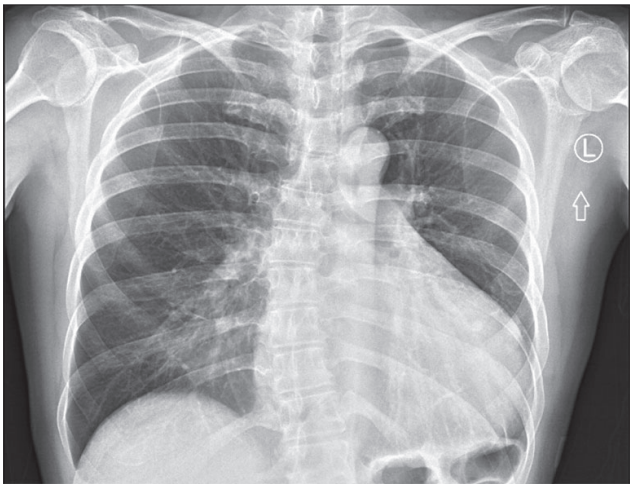

Figure 1. Chest radiograph on admission showing an enlarged cardiac silhouette without signs of pulmonary edema.

with right axis deviation, an S1Q3T3 pattern, and incomplete right bundle branch block (**Figure 2**).

DIFFERENTIAL DIAGNOSIS

1 What is the etiology of the patient's ECG findings?

- ☐ Chronic severe mitral regurgitation
- ☐ Pulmonary embolism
- ☐ Acute coronary syndrome
- ☐ Pulmonary hypertension

Given his presenting symptoms and history of chronic severe mitral regurgitation from mitral valve prolapse, the patient's presentation was consistent with acute heart failure exacerbation due to chronic severe mitral regurgitation. However, his ECG showed right axis deviation, incomplete right bundle branch block, the S1Q3T3 pattern (large S wave in lead 1, Q wave and inverted T wave in lead 3), and right ventricle strain in precordial leads, indicating right ventricular hypertrophy. These ECG features can be seen in acute pulmonary embolism or pulmonary hypertension, less so in acute coronary syndrome. The patient's younger age, minimal atherosclerotic risk factors, negative troponin, and lack of ECG signs of prior ischemic heart disease made acute coronary syndrome less likely.

Computed tomography pulmonary angiography showed no evidence of pulmonary embolism. It was thus possible that the patient's ECG pattern of right ventricular hypertrophy was due to pulmonary hypertension. Patients with severe mitral regurgitation can develop pulmonary hypertension.[1] However, the classic ECG pattern of mitral regurgitation includes left atrial enlargement, atrial fibrillation, left ventricular hypertrophy, or prior myocardial infarction. A recent study reported that in patients undergoing percutaneous mitral valve repair, the mean QRS axis before percutaneous mitral valve repair was −15.2 ± 6.1 degrees (mean ± standard error of the mean, n = 104),[2] whereas the QRS axis for this patient was 94 degrees. Additionally, the patient's ECG did not show a pattern of left ventricular hypertrophy, with small, narrow q waves, tall R waves with upright, tall T waves in leads V_5 and V_6, and deep S waves in leads V_1 and V_2, which, if present, would have been suggestive of left ventricular volume overload from mitral regurgitation.

CASE CONTINUED: TRANSTHORACIC ECHOCARDIOGRAPHY

Transthoracic echocardiography showed a left ventricular ejection fraction of more than 75%, severe right ventricular dilation, severe right ventricular systolic dysfunction, and severe eccentric, anteriorly directed mitral regurgitation due to severe posterior mitral valve leaflet prolapse (**Figure 3**). His left atrium was mildly dilated at 18.50 cm^2. His estimated pulmonary artery systolic pressure was 68 mm Hg.

A transthoracic echocardiogram obtained 5 years before this presentation was notable for severe mitral regurgitation due to prolapse of the posterior mitral valve leaflet with normal left atrium size, flow reversal in the pulmonary veins, and normal right ventricular size and function.

CAUSES OF PULMONARY HYPERTENSION

2 What is the etiology of the patient's pulmonary hypertension?

- ☐ Left heart failure from severe mitral regurgitation
- ☐ A complication of HIV therapy
- ☐ Other cause

The 2022 European Society of Cardiology and European Respiratory Society guidelines[3] define pulmonary hypertension as a mean pulmonary artery pressure of greater than 20 mm Hg and uses the following clinical classification structure:

- Group 1: Pulmonary arterial hypertension
- Group 2: Pulmonary hypertension due to left heart disease
- Group 3: Pulmonary hypertension associated with lung disease or hypoxemia, or both

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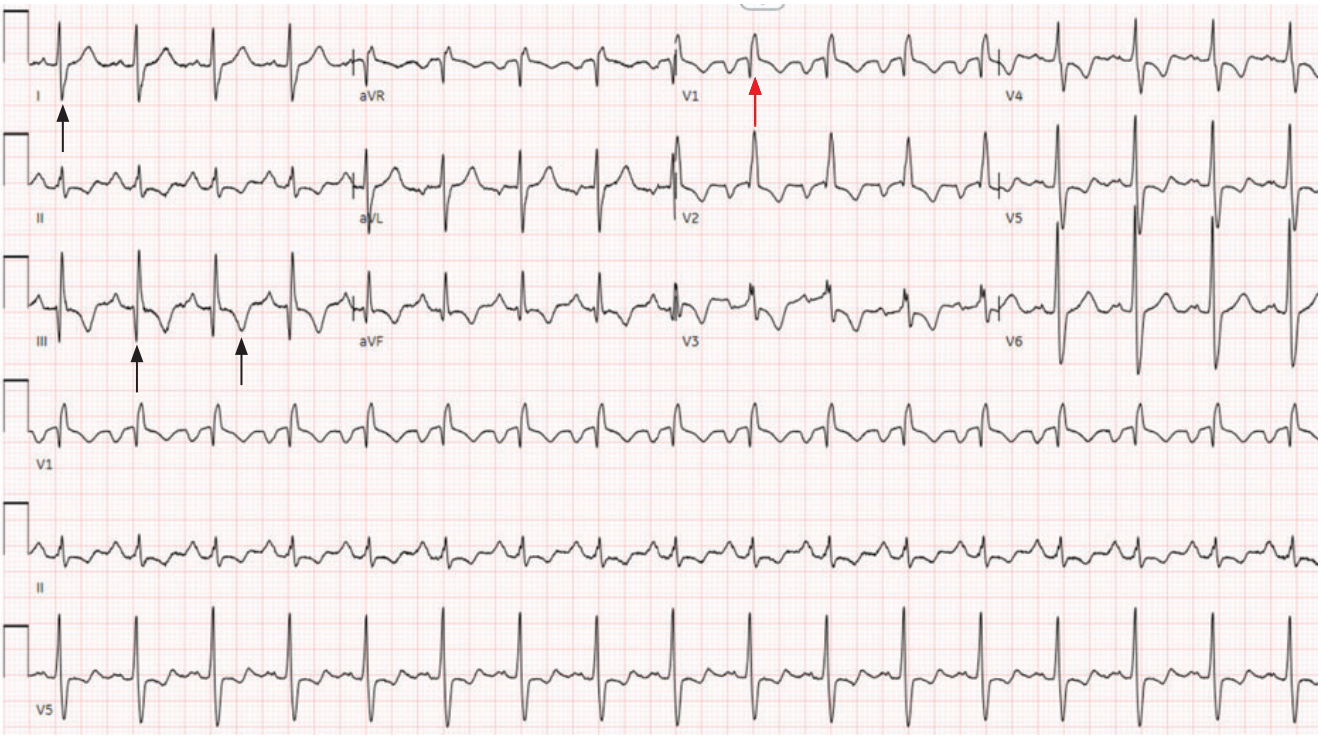

Figure 2. Twelve-lead electrocardiogram notable for sinus tachycardia with right axis deviation, S1Q3T3 pattern (large S wave in lead 1, Q wave and inverted T wave in lead 3 [black arrows]), and incomplete right bundle branch block (red arrow), indicating right ventricular hypertrophy.

- Group 4: Chronic thromboembolic pulmonary hypertension
- Group 5: Pulmonary hypertension due to unclear or multiple mechanisms.

Group 1 and group 2 pulmonary hypertension are relevant to this patient.

Mitral regurgitation and left heart disease

In this case, the patient has a known long-standing history of primary mitral regurgitation due to mitral valve prolapse. In the early compensated stage of mitral regurgitation, the volume overload associated with mitral regurgitation leads to left ventricle dilation and eccentric hypertrophy.[4] The left atrium also dilates to accommodate the increase in left atrium volume while maintaining left atrium compliance and thus normal filling pressures. Provided that forward stroke volume is maintained, patients can remain asymptomatic for years.

Over time, progressive left ventricle enlargement occurs because of the volume overload, causing left ventricle cavity dilation as well as mitral annular dilation, with progressively worsening mitral regurgitation. As mitral regurgitation worsens, the reversal of blood flow leads to volume overload and remodeling of the left atrium to accommodate the larger stroke volume, initially without a change in left atrial pressure. These anatomic changes explain the ECG findings of left atrial enlargement and left ventricular hypertrophy. Consequently, in the decompensated phase, left ventricle failure leads to increased left-sided filling pressures transmitted through the left ventricle, left atrium, and the pulmonary vasculature, leading to pulmonary hypertension.[4]

In a large multicenter international study of 437 patients with degenerative mitral regurgitation, pulmonary hypertension (defined as pulmonary artery systolic pressure > 50 mm Hg on transthoracic echocardiography) was noted in 23% of patients.[5]

HIV infection

In addition to mitral regurgitation, the patient also had a long-standing history of HIV, which increases the prevalence of pulmonary arterial hypertension by 100-fold, regardless of CD4 count.[6] While the exact mechanism is unknown, histopathologic characteristics of HIV-associated pulmonary arterial hypertension show the same findings associated with other forms of group 1 pulmonary hypertension—medial hypertrophy,

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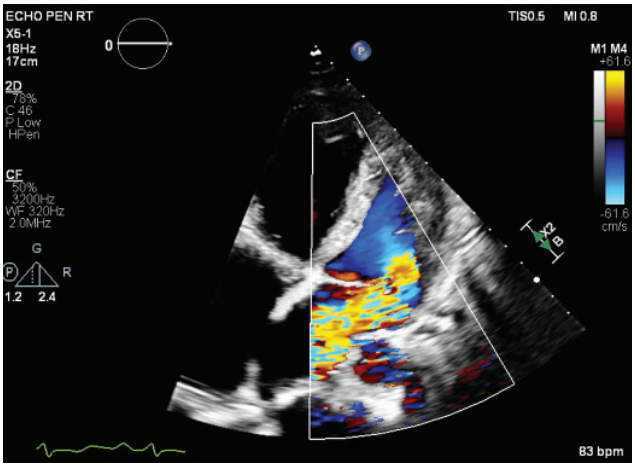

Figure 3. Transthoracic echocardiography apical 4-chamber color Doppler view showing severe eccentric, anteriorly directed mitral regurgitation (proximal isovelocity surface area radius 1.0 cm, aliasing velocity 61.6 cm/second, mitral regurgitation maximum velocity 411 cm/second, mitral valve velocity time integral 81.6 cm, effective regurgitant orifice area 0.94 cm^2, regurgitation volume 77 mL).

proliferation of endothelial and smooth muscle cells, and plexiform lesions, likely because of chronic inflammation and immune activation caused by HIV.[6]

At this juncture, it is unclear whether the patient's antiretroviral therapy contributed to his pulmonary hypertension. However, data from a retrospective study of more than 20,000 veterans suggest that improved HIV control with antiretroviral therapy is associated with a reduced risk of pulmonary hypertension detected on echocardiogram.[7]

DIAGNOSING PULMONARY HYPERTENSION

3 What is the next step in the workup for his pulmonary hypertension?

- ☐ Right heart catheterization
- ☐ Transesophageal echocardiography
- ☐ Computed tomography coronary angiography
- ☐ Left heart catheterization

The gold standard for diagnosis of pulmonary hypertension is right heart catheterization, which should be performed to confirm the diagnosis and support treatment decisions.[3] Transesophageal echocardiography, left heart catheterization, and computed tomography coronary angiography would not be able to measure precapillary and postcapillary pressures, which is necessary for the confirmation or diagnosis of pulmonary hypertension.

Pulmonary hypertension, defined by a mean pulmonary arterial pressure greater than 20 mm Hg, can be characterized as precapillary, postcapillary, and mixed pre- and postcapillary based on hemodynamic assessment by right heart catheterization.[3]

- Isolated postcapillary pulmonary hypertension: pulmonary capillary wedge pressure (PCWP) is higher than 15 mm Hg (normal ≤ 15) with a pulmonary vascular resistance of less than 2 Wood units (0.3–2.0)
- Precapillary pulmonary hypertension: PCWP is 15 mm Hg or less with a pulmonary vascular resistance of more than 2 Wood units
- Combined pre- and postcapillary pulmonary hypertension: PCWP is 15 mm Hg or more with a pulmonary vascular resistance of 2 Wood units or more.

A transpulmonary gradient (calculated as the difference between mean pulmonary artery pressure and PCWP) of 12 mm Hg or greater can be helpful for detecting intrinsic lung disease in the setting of cardiac disease and would result in the diagnosis of "out of proportion" pulmonary hypertension for the degree of left-sided cardiac disease.[8]

Elements of hemodynamic assessment

Obtaining accurate hemodynamic measurements during right heart catheterization starts with adequate preparation of patients. Further, the clinical context and imaging findings should always be considered when interpreting hemodynamic data.

The external pressure transducer should be zeroed at the phlebostatic axis, defined as the bisection of the fourth intercostal space at the midpoint between the anterior and posterior chest wall. Pressure should be measured at the end of expiration. Computer-generated digital mean pressure should not be used because the computer may not recognize and differentiate between an "a" wave and "v" wave, leading to erroneous readings.[9]

PCWP is commonly used in clinical practice to differentiate between pre- and postcapillary pulmonary hypertension; however, reliance on PCWP rather than left ventricle end-diastolic pressure can lead to misclassification of pulmonary venous hypertension as pulmonary arterial hypertension.[10] Thus, it is important to obtain measurements of PCWP and left ventricle end-diastolic pressure when hemodynamic measurements do not match the clinical context, such as in patients with chronic obstructive pulmonary disease or obesity.[11]

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Preexisting medical conditions, particularly blood pressure and volume status, must be optimally controlled at the time of examination. Avoiding sedatives such as opioids or benzodiazepines is important as these drugs can cause hypotension and hypoventilation.[12]

CASE CONTINUED: RIGHT HEART CATHETERIZATION

After achieving clinical euvolemia by diuresis, the patient underwent right heart catheterization, during which the following measurements were obtained:

- Mean right atrial pressure 0 mm Hg (2–6)
- Mean pulmonary artery pressure 30 mm Hg (8–20)
- Pulmonary artery systolic 51 mm Hg (15–30)
- Pulmonary artery diastolic 18 mm Hg (4–12)
- PCWP 6 mm Hg
- Pulmonary vascular resistance 6.5 Wood units.

These findings indicate the presence of isolated precapillary pulmonary hypertension. His transpulmonary gradient was 24, suggestive of "out of proportion" pulmonary hypertension for his cardiac disease.

Workup for alternate etiologies of pulmonary hypertension, including connective tissue disease, chronic thromboembolic pulmonary hypertension, primary lung disease, sarcoidosis, and myeloproliferative disorder, was unremarkable. Medication history was unrevealing for any medications known to cause pulmonary hypertension, aside from a remote history of methamphetamine use. The only risk factor identified was the patient's history of HIV infection.

The patient was thus diagnosed with World Health Organization group 1 pulmonary hypertension, in addition to severe mitral regurgitation from mitral valve prolapse. After discussion about risks and benefits of intravenous prostanoid therapy, the patient opted to start oral sildenafil and selexipag for pulmonary arterial hypertension. Anticoagulation was discussed and ultimately deferred by the patient due to concerns about potential harm and pill burden.

MITRAL REGURGITATION TREATMENT OPTIONS

4 What is the next best step in the treatment of his severe mitral regurgitation from mitral valve prolapse?

- ☐ Clinical follow-up and serial echocardiography
- ☐ Referral to cardiac surgery for mitral valve repair
- ☐ Referral to interventional cardiology for percutaneous mitral valve clipping
- ☐ Guideline-directed medical therapy

TABLE 1
Variables used to calculate REVEAL 2.0 risk score

World Health Organization group 1 subgroup
Presence of renal insufficiency
Male age greater than 60
New York Heart Association/World Health Organization functional class
Systolic blood pressure
Heart rate
Six-minute walk test distance
Level of B-type natriuretic peptide
Presence of pericardial effusion
Diffusing capacity of the lung for carbon monoxide on pulmonary function test
Elevated atrial pressures
Any hospitalization within 6 months
Pulmonary vascular resistance

REVEAL = Registry to Evaluate Early and Long-Term PAH Disease Management

Information from reference 13.

There is no straight answer for this patient as he has 2 concomitant diseases, with pulmonary hypertension posing higher procedure risk for mitral valve intervention. The REVEAL 2.0 score (Registry to Evaluate Early and Long-Term PAH Disease Management) is used to predict survival in patients with pulmonary arterial hypertension based on 13 variables (**Table 1**).[13] The patient's REVEAL 2.0 score was 14, putting him in a high-risk subgroup (≥ 9) with 1-year survival predictions lower than 70%. (A REVEAL 2.0 calculator is available online: www.mdcalc.com/calc/10071/reveal-registry-risk-score-pulmonary-arterial-hypertension-pah)

The 2022 European Society of Cardiology and European Respiratory Society guidelines[3] recommend attempting to optimize peripheral arterial hypertension therapy before surgery, and also note that the mortality risk of surgical procedures is associated with the severity of pulmonary hypertension. Factors such as N-terminal pro–B-type natriuretic peptide higher than 300 pg/mL, New York Heart Association functional class 3 or 4, renal insufficiency, hospitalization within 6 months, and urgency of surgery have been independently associated with increased postoperative mortality in noncardiac surgery.[14,15] It stands to reason these risk factors are also associated with worse outcomes in patients undergoing cardiac surgery.

All patients with severe mitral regurgitation should undergo an assessment to determine the cause of

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their mitral regurgitation.[16] Patients with symptomatic severe primary mitral regurgitation should be referred for mitral valve repair with cardiac surgery, which is preferred over mitral valve replacement but may not always be technically feasible. All patients with severe primary mitral regurgitation with features of cardiac remodeling (ejection fraction ≤ 60%, left ventricle end-systolic diameter ≥ 4 cm, pulmonary artery systolic pressure > 50 mm Hg, new atrial fibrillation, or progressive decrease in left ventricle ejection fraction over time) should be referred for surgical management as well.

Given the patient's initial presenting symptoms suggesting left-sided heart failure, referring him for mitral valve intervention after starting him on adequate pulmonary hypertension therapy would have been reasonable. Stress echocardiography to assess change of systolic pulmonary arterial pressure during exercise could have been helpful in attributing his symptoms to mitral regurgitation. Referral to pulmonary hypertension specialists to optimize his perioperative care also would have been appropriate.

The mode of mitral intervention, surgically vs percutaneously, in the setting of group 1 pulmonary hypertension is another concern. Given the patient's high REVEAL score, we believe percutaneous mitral valve repair was a reasonable option to avoid intubation, cardiopulmonary bypass, fluid shift, and postoperative pulmonary complications. Other surgical risk assessments for surgical vs percutaneous mitral valve repair should include the patient's Society of Thoracic Surgeons predicted risk of mortality, frailty assessment, cardiac or other major organ system compromise not to be improved postoperatively, and procedure-specific impediment.[17] The decision should be made by a multidisciplinary team involving a pulmonary hypertension specialist and based on individual risk vs benefit factors such as indication, urgency, severity of pulmonary hypertension, and patient preference.[3]

CASE DISCUSSION

This was an unusual case of a patient with heart failure symptoms that were initially attributed to severe mitral regurgitation and resultant group 2 pulmonary hypertension, with an initial plan for mitral valve intervention. However, the right ventricular hypertrophy patterns on ECG were less consistent with isolated severe mitral regurgitation and raised the suspicion that the patient's pulmonary hypertension was not due to severe mitral regurgitation alone. ECG findings in mitral regurgitation are often nonspecific and consist of left atrial enlargement, atrial fibrillation, left ventricular hypertrophy, or changes suggesting concomitant myocardial infarction.[2]

ECG signs suggesting pulmonary hypertension or right ventricular hypertrophy are not common in isolated mitral regurgitation. In a group of 65 patients with rheumatic mitral regurgitation, only 9.2% and 1.5% of patients had right ventricular hypertrophy and right ventricular hypertrophy with incomplete right bundle branch block, respectively.[18] In a group of 23 patients with mitral regurgitation of mixed etiology, only 4.3% and 8.6% of patients had right ventricular hypertrophy or combined ventricular hypertrophy, respectively.[19]

However, the presence of right ventricular hypertrophy on ECG in patients with mitral regurgitation does indicate advanced disease, with pulmonary hypertension and high PCWP indicating left heart failure as well.[20] These published data are from the pre-echocardiography era and included mostly patients with rheumatic mitral regurgitation. The true incidence of ECG patterns of right ventricular hypertrophy or right ventricular strain is not known in nonrheumatic mitral regurgitation as contemporary data from the the EVEREST II (Endovascular Valve Edge-to-Edge Repair Study),[21] COAPT (Cardiovascular Outcomes Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients With Functional Mitral Regurgitation),[22] and MITRA-FR (Percutaneous Repair with the MitraClip Device for Severe Functional/Secondary Mitral Regurgitation)[23] trials did not provide ECG descriptions.

In addition, this case illustrates a potential anchoring bias, a common cognitive bias that influences physician decision-making. Anchoring bias refers to the practice of prioritizing information and data that support one's initial impressions, even if those impressions are incorrect. A 2016 systematic review of the available evidence on cognitive biases showed that cognitive bias may affect 50% to 100% of physicians and was associated with diagnostic inaccuracies in 36.5% to 77% of case scenarios.[24] In this case, the patient was being admitted for dyspnea and had a history of mitral regurgitation and heart failure exacerbations. The patient's dyspnea was attributed to heart failure exacerbation caused by mitral regurgitation, and the patient was evaluated for mitral valve intervention. Further review led to investigation with a right heart catheterization and a diagnosis of pulmonary arterial hypertension, which changed the patient's treatment trajectory.

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Modern cardiology has evolved to rely heavily on echocardiography and advanced imaging modalities for diagnostic and therapeutic decision-making. Reliance on advanced imaging modalities is growing in daily practice due to the complexity of patient presentations and advances in therapeutics for patients with increasingly complex structural heart disease. Although ECG reading skills are still being taught at bedside daily, less time and effort has been spent analyzing and correlating ECG findings with clinical data and imaging findings. This case illustrated a potentially biased diagnosis and therapy plan based on history and imaging, with ECG interpretation playing a key role in correcting the bias.

CASE CONCLUSION

The patient was started on dual oral therapy for pulmonary arterial hypertension with sildenafil and selexipag, with plans to address his mitral valve prolapse after his pulmonary arterial hypertension was better controlled.

TAKE-HOME POINTS

- Patients who have discordant clinical presentations and diagnostic studies require a wide differential diagnosis to avoid premature closure or anchoring bias.
- Electrocardiography remains an integral part of diagnostic workup and should be interpreted together with the clinical picture to establish a diagnosis.

DISCLOSURES

The authors report no relevant financial relationships which, in the context of their contributions, could be perceived as a potential conflict of interest.

REFERENCES

1. **Alexopoulos D, Lazzam C, Borrico S, Fiedler L, Ambrose JA.** Isolated chronic mitral regurgitation with preserved systolic left ventricular function and severe pulmonary hypertension. J Am Coll Cardiol 1989; 14(2):319–322. doi:10.1016/0735-1097(89)90180-0
2. **Bo H, Heinzmann D, Grasshoff C, et al.** ECG changes after percutaneous edge-to-edge mitral valve repair. Clin Cardiol 2019; 42(11):1094–1099. doi:10.1002/clc.23258
3. **Humbert M, Kovacs G, Hoeper MM, et al.** 2022 ESC/ERS guidelines for the diagnosis and treatment of pulmonary hypertension. Eur Respir J 2023; 61(1):2200879. doi:10.1183/13993003.00879-2022
4. **Patel H, Desai M, Tuzcu EM, Griffin B, Kapadia S.** Pulmonary hypertension in mitral regurgitation. J Am Heart Assoc 2014; 3(4):e000748. doi:10.1161/JAHA.113.000748
5. **Barbieri A, Bursi F, Grigioni F, et al.** Prognostic and therapeutic implications of pulmonary hypertension complicating degenerative mitral regurgitation due to flail leaflet: a multicenter long-term international study. Eur Heart J 2011; 32(6):751–759. doi:10.1093/eurheartj/ehq294
6. **Almodovar S, Cicalini S, Petrosillo N, Flores SC.** Pulmonary hypertension associated with HIV infection: pulmonary vascular disease: the global perspective. Chest 2010; 137(6 suppl):6S–12S. doi:10.1378/chest.09-3065
7. **Duncan MS, Alcorn CW, Freiberg MS, et al.** Association between HIV and incident pulmonary hypertension in US Veterans: a retrospective cohort study. Lancet Healthy Longev 2021; 2(7):e417–e425. doi:10.1016/s2666-7568(21)00116-1
8. **Naeije R, Vachiery JL, Yerly P, Vanderpool R.** The transpulmonary pressure gradient for the diagnosis of pulmonary vascular disease. Eur Respir J 2013; 41(1):217–223. doi:10.1183/09031936.00074312
9. **Krishnan A, Markham R, Savage M, Wong YW, Walters D.** Right heart catheterisation: how to do it. Heart Lung Circ 2019; 28(4): e71–e78. doi:10.1016/j.hlc.2018.08.005
10. **Halpern SD, Taichman DB.** Misclassification of pulmonary hypertension due to reliance on pulmonary capillary wedge pressure rather than left ventricular end-diastolic pressure. Chest 2009; 136(1): 37–43. doi:10.1378/chest.08-2784
11. **Bitar A, Selej M, Bolad I, Lahm T.** Poor agreement between pulmonary capillary wedge pressure and left ventricular end-diastolic pressure in a veteran population. PLoS One 2014; 9(1):e87304. doi:10.1371/journal.pone.0087304
12. **Gonzalez-Hermosillo LM, Cueto-Robledo G, Roldan-Valadez E, et al.** Right heart catheterization (RHC): a comprehensive review of provocation tests and hepatic hemodynamics in patients with pulmonary hypertension (PH). Curr Probl Cardiol 2022; 47(12):101351. doi:10.1016/j.cpcardiol.2022.101351
13. **Benza RL, Gomberg-Maitland M, Elliott CG, et al.** Predicting survival in patients with pulmonary arterial hypertension: The REVEAL Risk Score Calculator 2.0 and comparison with ESC/ERS-based risk assessment strategies. Chest 2019; 156(2):323–337. doi:10.1016/j.chest.2019.02.004
14. **Deljou A, Sabov M, Kane GC, et al.** Outcomes after noncardiac surgery for patients with pulmonary hypertension: a historical cohort study. J Cardiothorac Vasc Anesth 2020; 34(6):1506–1513. doi:10.1053/j.jvca.2019.10.059
15. **Rajagopal S, Ruetzler K, Ghadimi K, et al.** Evaluation and management of pulmonary hypertension in noncardiac surgery: a scientific statement from the American Heart Association. Circulation 2023; 147(17):1317–1343. doi:10.1161/CIR.0000000000001136
16. **Bonow RO, O'Gara PT, Adams DH, et al.** 2020 focused update of the 2017 ACC expert consensus decision pathway on the management of mitral regurgitation: a report of the American College of Cardiology Solution Set Oversight Committee [published correction appears in J Am Coll Cardiol 2020; 75(23):3000]. J Am Coll Cardiol 2020; 75(17):2236–2270. doi:10.1016/j.jacc.2020.02.005
17. **Otto CM, Nishimura RA, Bonow RO, et al.** 2020 ACC/AHA guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines [published correction appears in Circulation 2021; 143(5):e229] [published correction appears in Circulation 2023; 148(8):e8] [published correction appears in Circulation 2023; 148(20):e185] [published correction appears in Circulation 2024; 150(12):e267]. Circulation 2021; 143(5):e72–e227. doi:10.1161/CIR.0000000000000923
18. **Bentivoglio LG, Uricchio JF, Waldow A, Likoff W, Goldberg H.** An electrocardiographic analysis of sixty-five cases of mitral regurgitation. Circulation 1958; 18(4 Part 1):572–580. doi:10.1161/01.cir.18.4.572
19. **Ross J Jr, Braunwald E, Morrow AG.** Clinical and hemodynamic observations in pure mitral insufficiency. Am J Cardiol 1958; 2(1):11–23. doi:10.1016/0002-9149(58)90244-3
20. **Bentivoglio L, Uricchio JF, Likoff W.** The paradox of right ventricular enlargement in mitral insufficiency. Am J Med 1958; 24(2):193–202. doi:10.1016/0002-9343(58)90307-3

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21. **Feldman T, Foster E, Glower DD, et al.** Percutaneous repair or surgery for mitral regurgitation [published correction appears in N Engl J Med 2011; 365(2):189. Glower, Donald G [corrected to Glower, Donald D]]. N Engl J Med 2011; 364(15):1395–1406. doi:10.1056/NEJMoa1009355
22. **Stone GW, Lindenfeld J, Abraham WT, et al.** Transcatheter mitral-valve repair in patients with heart failure. N Engl J Med 2018; 379(24):2307–2318. doi:10.1056/NEJMoa1806640
23. **Obadia JF, Messika-Zeitoun D, Leurent G, et al.** Percutaneous repair or medical treatment for secondary mitral regurgitation. N Engl J Med 2018; 379(24):2297–2306. doi:10.1056/NEJMoa1805374
24. **Saposnik G, Redelmeier D, Ruff CC, Tobler PN.** Cognitive biases associated with medical decisions: a systematic review. BMC Med Inform Decis Mak 2016; 16(1):138. doi:10.1186/s12911-016-0377-1

Address: *Kuang-Yuh Chyu, MD, PhD, Department of Cardiology, Smidt Heart Institute, Cedars Sinai Medical Center, 127 South San Vicente Boulevard, Suite A-3318, Los Angeles, CA 90048; chyuk@cshs.org*

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