

VALVULAR HEART DISEASE

CASE REPORT: CLINICAL CASE

Bileaflet Tethering With Preserved LV Geometry and Function



An Unusual Mechanism of Functional Mitral Regurgitation

Dario Donia, MD,^{a,b} Kamil Stankowski, MD,^{a,b} Stefano Figliozzi, MD,^b Carlo Andrea Pivato, MD,^{a,b} Damiano Regazzoli, MD,^b Antonio Mangieri, MD,^b Bernhard Reimers, MD,^b Renato Maria Bragato, MD,^b Giulio Stefanini, MD, PhD,^{a,b} Francesco Cannata, MD, PhD^{b,c}

ABSTRACT

An 81-year-old woman presented with acute pulmonary edema. Echocardiography revealed severe functional mitral regurgitation, the mechanism of which was unusual. An atypical bileaflet tethering caused by disharmonic annular remodeling, concomitant aortic dilatation, and reduced aorto-mitral angle without left ventricular dysfunction or dilatation was found. A transcatheter edge-to-edge repair was nonetheless successfully performed. (J Am Coll Cardiol Case Rep 2024;29:102191) © 2024 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

An 81-year-old woman presented to our emergency department for acute dyspnea with signs of central congestion. She was afebrile, with blood pressure of 110/60 mm Hg, an irregular heart rate of 60 beats/min, and a respiratory rate of 32 breaths/min. Physical examination revealed bilateral mid-basilar rales and a

systolic murmur at the cardiac apex. Her medications included torsemide 15 mg, bisoprolol 2.5 mg, ramipril 5 mg, rivaroxaban 20 mg, spironolactone 50 mg, and levothyroxine 50 µg. The patient was admitted to the cardiology ward.

PAST MEDICAL HISTORY

The patient's medical history was notable for paroxysmal atrial fibrillation, previous pulmonary vein isolation, and pacemaker implantation for bradycardia-tachycardia syndrome. Previous transthoracic echocardiography (TTE) showed preserved left ventricular ejection fraction (LVEF) with mild septal hypertrophy and mild mitral regurgitation (MR). Comorbidities included hypertension, dyslipidemia, hypothyroidism, and essential thrombocythemia.

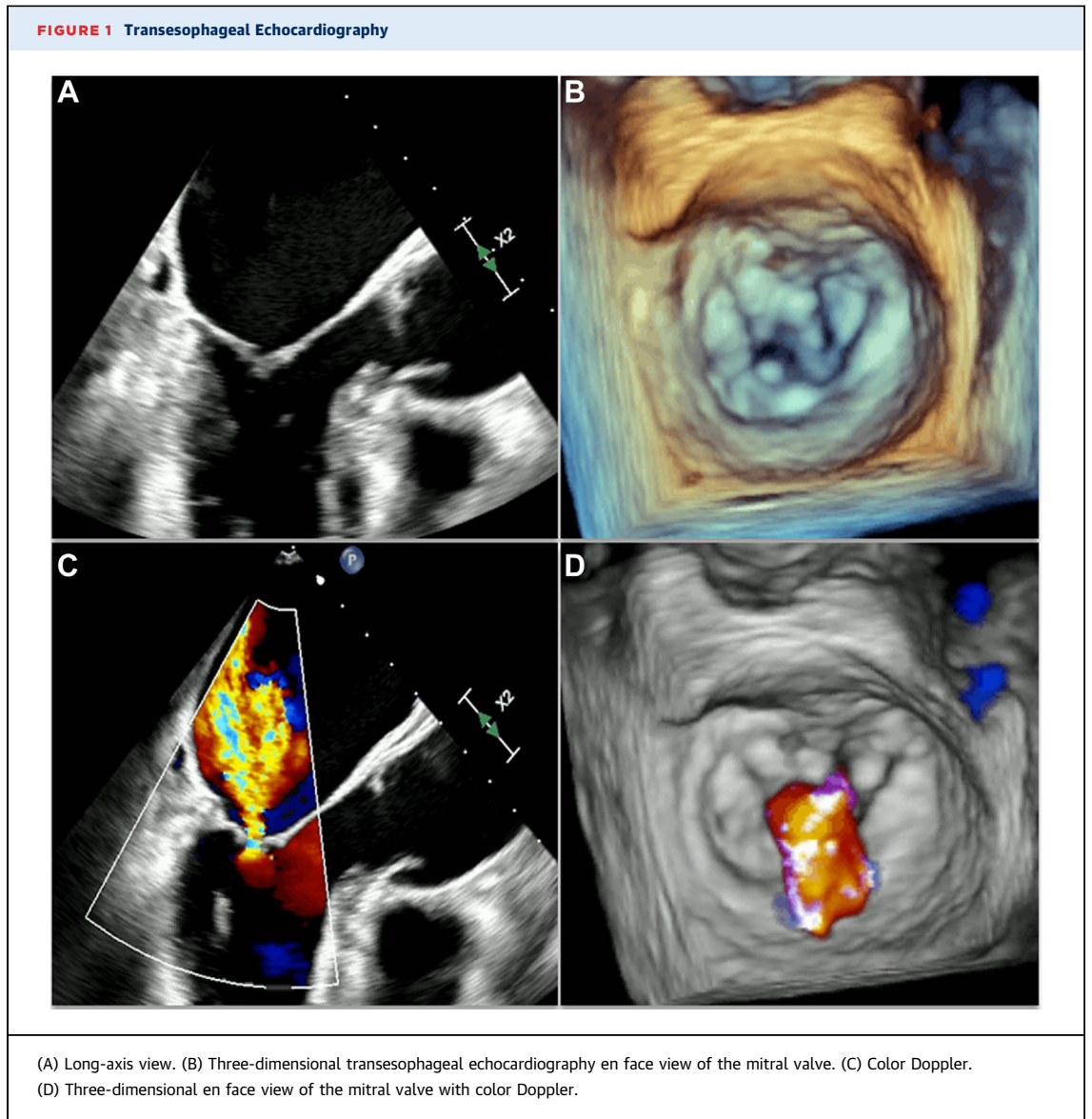
LEARNING OBJECTIVES

- To recognize FMR as a potential cause of acute heart failure.
- To identify unusual mechanisms of FMR such as bileaflet tethering in the absence of LV remodeling.
- To select percutaneous mitral valve repair as a treatment strategy for patients with FMR.

From the ^aDepartment of Biomedical Sciences, Humanitas University, Milan, Italy; ^bIRCCS Humanitas Research Hospital, Milan, Italy; and the ^cDepartment of Perioperative Cardiology and Cardiovascular Imaging, Centro Cardiologico Monzino IRCCS, Milan, Italy.

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DIFFERENTIAL DIAGNOSIS

Potential causes of acute heart failure included myocardial ischemia, atrial fibrillation with rapid ventricular response, valvular heart disease, and pacing-induced cardiomyopathy.

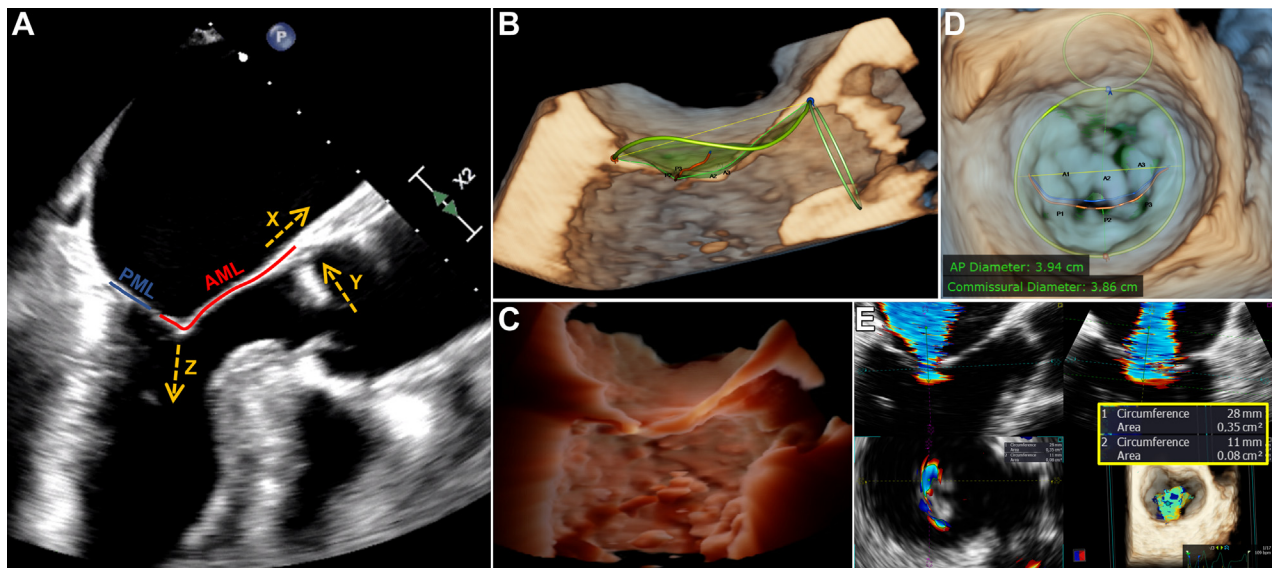
INVESTIGATIONS

The patient's electrocardiogram showed appropriate on-demand ventricular stimulation with underlying atrial fibrillation. Results of laboratory tests showed

normal levels of high-sensitivity troponin I, inflammatory markers, and hemoglobin. B-type natriuretic peptide levels were elevated (653 pg/mL). Chest radiography showed interstitial-alveolar edema.

TTE revealed a nondilated left ventricle with preserved LVEF (61%) with an inferolateral hypokinesia (Video 1). Severe MR was diagnosed and deemed an atypical functional MR (FMR) (Videos 2 and 3). Right ventricular function was normal, with moderate tricuspid regurgitation and elevated systolic pulmonary artery pressure (50 mm Hg). A coronary angiography excluded critical stenoses (Video 4).

FIGURE 2 Novel Mechanism of Functional Mitral Regurgitation



(A) Transesophageal echocardiography long-axis view showing disharmonic atrial and annular dilatation (x), concomitant aortic dilatation (y) and tethering forces exerted by the papillary muscles (z). (B) Three-dimensional reconstruction of the mitral valve using a commercially available software (TOMTEC Imaging Systems). (C) Three-dimensional reconstruction of the mitral valve with transillumination rendering (FlexiLight; GE Healthcare). (D) Reconstruction of the mitral annulus, using TOMTEC software, emphasizing disharmonic annular remodeling, with measures of antero-posterior (AP) (3.94 cm) and commissural (3.86 cm) diameters. (E) Assessment of 3-dimensional vena contracta area (0.43 cm²), with multiplanar reconstruction of a color Doppler 3-dimensional data set. AML = anterior mitral leaflet; PML = posterior mitral leaflet.

MANAGEMENT

Despite an aggressive intravenous diuretic treatment regimen, the patient continued to be symptomatic and congested, while severe MR remained. Hence, transesophageal echocardiography (TEE) was performed to assess the feasibility of percutaneous repair.

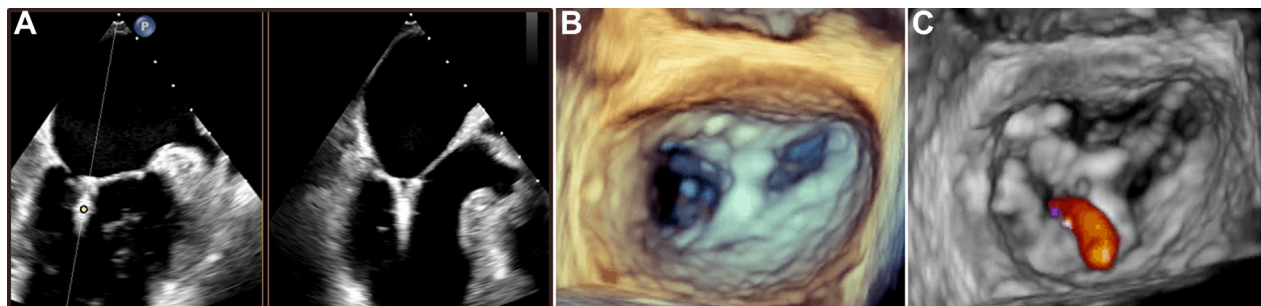
TEE confirmed the severity (Figure 1, Videos 5 to 8) and the unusual mechanism of the FMR in which concomitant anatomical alterations caused atypical bileaflet tethering in the absence of left ventricular (LV) dysfunction or dilatation. The regional infero-lateral hypokinesia alone could not explain the bileaflet tethering. Indeed, after a careful evaluation, we could appreciate the tethering of the posterior leaflet, caused by both the regional hypokinesia and a disproportionate left atrial (LA) dilatation compared with the nondilated left ventricle; the result was disharmonic annular remodeling and equal antero-posterior and commissural diameters. Furthermore, the concomitant aortic root dilatation and reduced aorto-mitral angle emphasized the superior and anterior displacement of the hinge point of the anterior leaflet and thus determined its tethering

(Figure 2). This novel mechanism resulted in a regurgitant jet between the A2 and P2 scallops, directed toward the posterior atrial wall.

Notwithstanding the unusual mechanism of MR, the Heart Team decided on mitral transcatheter edge-to-edge repair (TEER) with a MitraClip device (Abbott Vascular). A single XTW clip was successfully implanted in the centromedial position (Figure 3, Video 9), creating a double-orifice mitral valve with a single mild residual regurgitant jet from the lateral orifice and halving the LA pressures (Video 10).

DISCUSSION

FMR occurs due to ventricular or atrial remodeling without an organic mitral valve disease.¹ Ventricular FMR is generally secondary to ischemic or non-ischemic LV systolic dysfunction/dilatation, consequent papillary muscle displacement, and tethering of mitral valve leaflets (Carpentier IIIB), together with reduced closing forces due to LV contractility impairment. The tethering mechanism may involve both leaflets, in case of global LV dysfunction/dilatation, or only the posterior leaflet, in case of a regional LV remodeling of the inferior-posterior wall.

FIGURE 3 Transcatheter Edge-to-Edge Repair

(A) Transesophageal echocardiography biplane view of commissural and long-axis views showing a single XTW clip implanted in a centromedial position.

(B) Three-dimensional en face view of the mitral valve showing the tissue bridge between the anterior and posterior leaflets and the resulting double-orifice mitral valve. (C) Three-dimensional en face view of the mitral valve with color Doppler showing a single residual regurgitant jet from the lateral orifice.

Atrial FMR, instead, is the result of LA enlargement (Carpentier I), with preserved LV geometry and function. Two mechanisms underpinning atrial FMR have been proposed so far: 1) LA dilatation leading to mitral annular enlargement and insufficient leaflet remodeling; and 2) atrigenic tethering of the posterior mitral leaflet caused by posterior dilatation of the mitral annulus displacing the hinge line of the posterior leaflet over the crest of the LV myocardium.²

To the best of our knowledge, our report is the first case of significant MR due to bileaflet tethering (Carpentier IIIb) with mitral annulus dilatation in the presence of preserved LV geometry and function. We hypothesize that this peculiar mechanism results from the complex interactions between the previously mentioned alterations: regional posterior hypokinesia, disproportionate LA dilatation, disharmonic annular remodeling (mainly in anterior-posterior direction with consequent equality of anterior-posterior and intercommissural diameters), and aortic root dilatation with reduced aorto-mitral angle. Hence, this atypical MR undermines the traditional chamber-based classification of FMR (atrial FMR with mitral annulus dilatation and normal LV vs ventricular FMR with leaflet tethering due to LV dilatation/dysfunction) and suggests that FMR results from a complex interplay between LV and LA anatomical factors. Indeed, recent evidence shows that many cases of traditionally defined atrial FMR show a significant degree of leaflet tethering, even with normal LV geometry.³ The analysis of mitral

leaflet coaptation pattern with leaflet tethering or flattening may provide more clues about MR mechanism and its clinical impact than traditional chamber-based classification and has been shown to improve the prognostic stratification of patients with FMR.⁴

The COAPT (Cardiovascular Outcomes Assessment of the MitraClip Percutaneous Therapy for Heart Failure Patients with Functional Mitral Regurgitation) trial showed the benefit of TEER in patients with FMR and reduced LVEF (ie, $\leq 50\%$). However, the subsequent core laboratory-assessed LVEF subanalysis revealed that some patients had LVEF $>50\%$. As in the COAPT trial, pure atrial FMRs due to annular dilatation were theoretically excluded, it would be intriguing to analyze the MR mechanism of this subgroup of patients with preserved LV function.⁵ Hence, our case helps to shed light on the limitations of the current understanding of MR pathophysiology and of the chamber-based classification of FMR. The complex interactions between closing and tethering forces of mitral leaflets may go beyond strict classification schemes.

Notwithstanding the peculiar MR mechanism, our case confirms that TEER may be suitable for FMR after guideline-directed medical therapy. Leaflet tethering is a challenging anatomical element for TEER, associated with higher procedural complexity and suboptimal results. However, depending on the operator's expertise, optimal results can still be achieved even with significant tethering, as shown by this case.

FOLLOW-UP

Before the patient's discharge, TTE confirmed the good result of the procedure. At 1-year follow-up, she was asymptomatic, had no recurrent heart failure hospitalizations, and subsequent TTE confirmed mild residual MR.

CONCLUSIONS

Bileaflet tethering without LV dysfunction or dilatation is a rare and underrecognized mechanism of

FMR, potentially amenable to percutaneous repair with commercially available devices.

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ADDRESS FOR CORRESPONDENCE: Dr Francesco Cannata, Department of Perioperative Cardiology and Cardiovascular imaging, Centro Cardiologico Monzino IRCCS, Milan, Italy. E-mail: cannatafrancesco90@gmail.com. [@FrancescoC90](https://twitter.com/FrancescoC90).

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KEY WORDS bileaflet tethering, functional mitral regurgitation, 3-dimensional echocardiography, transesophageal echocardiography, transcatheter edge-to-edge repair

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