Intra-Aortic Balloon Pump Exacerbates Left Ventricular Outflow Tract Obstruction in a Patient With Takotsubo and Hypertrophic Cardiomyopathy

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INTRODUCTION

Traditionally, patients with cardiogenic shock from takotsubo cardiomyopathy require intravenous inotropic or, in some cases, mechanical hemodynamic support. However, for patients who have decompensated hypertrophic cardiomyopathy (HCM) and severe left ventricular outflow tract (LVOT) obstruction, the goal is to decrease inotropy while maintaining or even increasing afterload. Here we present a patient with takotsubo cardiomyopathy in the setting of HCM, which limited the effectiveness of norepinephrine and intra-aortic balloon pump (IABP) therapies. In addition to clinical data, echocardiographic images demonstrated a markedly increased LVOT gradient during 1:1 counterpulsation with the IABP and an immediate decrease in the gradient when the IABP was paused.

For patients with combined hypertrophic and takotsubo cardiomyopathy, hypotension should be managed with pure α agonists, while avoiding inotropic agents and IABPs. Venoarterial extracorporeal membrane oxygenation (VA-ECMO) may be preferred in cases of refractory shock.

CASE PRESENTATION

A 63-year-old man presented to the hospital with chest pain and progressive exertional dyspnea. Initial vital signs showed a heart rate of 104 beats/min, blood pressure of 141/71 mm Hg and O_2 saturation of 100% on room air. The physical examination was notable for a systolic murmur. The patient had a history of hypertension, coronary artery disease with prior treatment of in-stent restenosis in the left circumflex artery, as well as HCM with asymmetric septal hypertrophy (19 mm) and a previously documented LVOT gradient, for which they were treated with diltiazem and metoprolol.

The differential diagnosis for this patient's chest pain, shortness of breath, and electrocardiographic changes included an acute coronary syndrome, worsening HCM, and acute myocarditis.

Compared with the baseline electrocardiogram, which demonstrated left ventricular hypertrophy (Figure 1A), the patient had more prominent ST-segment elevation in leads V_2 and V_3, a new evolving biphasic T-wave in lead V_3, and symmetric T-wave inversions in leads I, aVL, and V_4 to V_6 (Figure 1B).

Troponin I was elevated at 0.63 ng/mL, and point-of-care echocardiography demonstrated anterior and anteroseptal akinesis and reduced left ventricular systolic function with an ejection fraction of 28% by Simpson's biplane method. Brain natriuretic peptide was elevated at 3,787 pg/mL.

VIDEO HIGHLIGHTS

Video 1: Coronary angiography of the left system demonstrates nonobstructive coronary artery disease. Reduced image quality is due to elevated heart rate and rapid contrast washout.
Video 2: Two-dimensional transthoracic echocardiography, apical four-chamber view with administration of ultrasound enhancing agent, demonstrating the large wall motion abnormality with apical akinesis.
Video 3: Two-dimensional transthoracic echocardiography, parasternal long-axis view, without (*left*) and with (*right*) color flow Doppler, demonstrating flow acceleration in the LVOT.
Video 4: Two-dimensional transthoracic echocardiography, apical three-chamber view, without (*left*) and with (*right*) color flow Doppler, IABP counterpulsating at a 1:1 ratio, demonstrating flow acceleration and SAM of the mitral valve.
Video 5: Two-dimensional transthoracic echocardiography, apical three-chamber view, without (*left*) and with (*right*) color flow Doppler, IABP on standby, demonstrates no flow acceleration and no SAM of the mitral valve.

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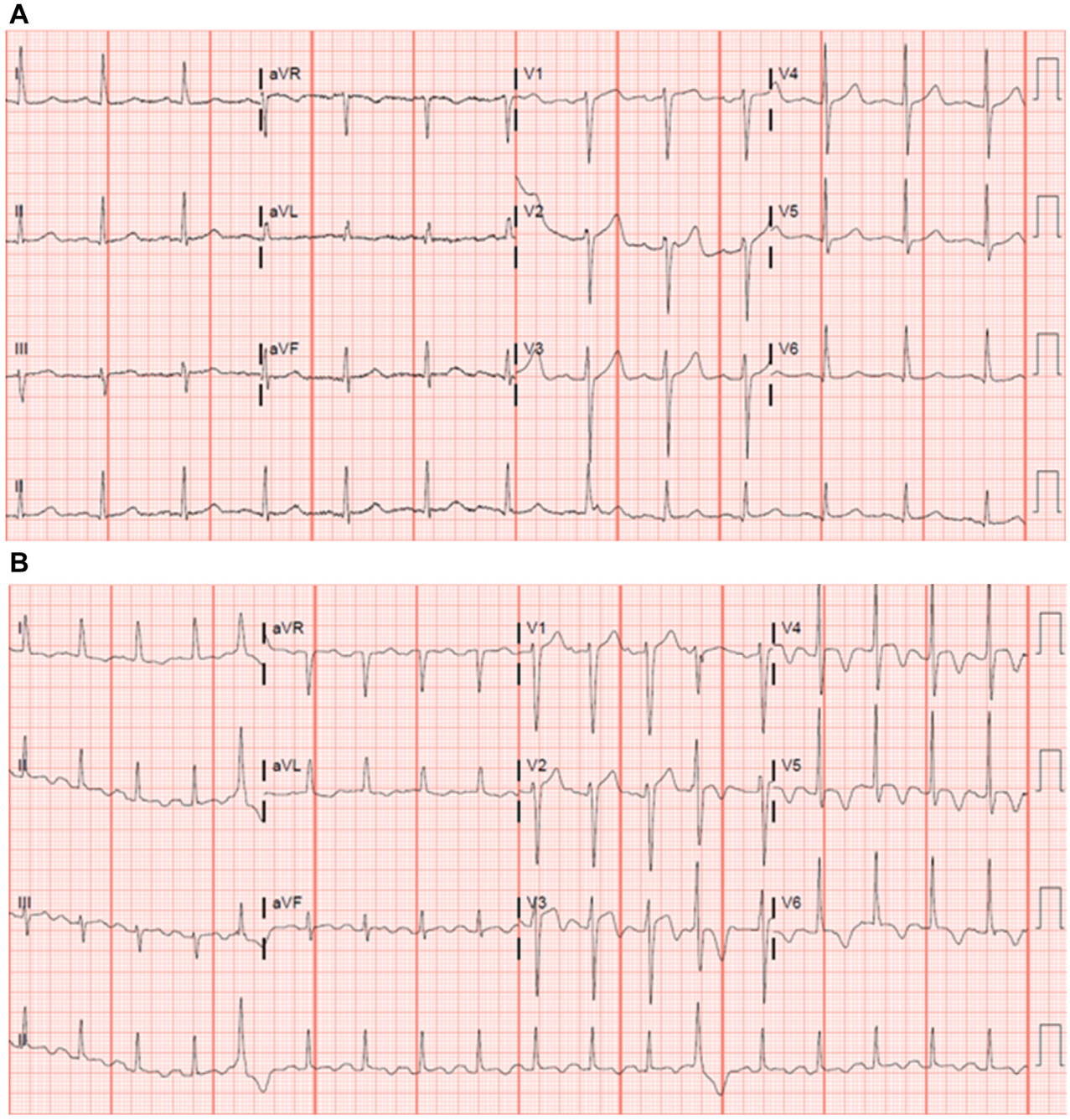

Figure 1 Electrocardiographic tracing at baseline **(A)** demonstrating left ventricular hypertrophy and at presentation **(B)** demonstrating new T-wave inversions in leads V_4 to V_6, I, and aVL and more pronounced ST-segment elevation in V_2 and V_3.

Urgent coronary angiography was performed for presumed acute coronary syndrome and revealed a 40% to 50% left anterior descending artery stenosis, unchanged from 3 months prior, and patent left circumflex artery stents (Video 1). As a culprit lesion was not identified, coronary intervention was not performed. Left ventricular end-diastolic pressure was 36 mm Hg, and there was a 38 mm Hg gradient on pullback from the left ventricle to the aorta. Intraprocedurally, the patient developed worsening shortness of breath and hypoxemia requiring intubation and subsequent hypotension with a systolic blood pressure of 80 mm Hg. Norepinephrine was started, and an IABP was placed. Right heart catheterization revealed elevated filling pressures (pulmonary capillary wedge pressure of 40 mm Hg) and a cardiac index of 2.8 L/min/m^2.

Follow-up transthoracic echocardiography demonstrated severe left ventricular dysfunction with akinesis of the mid and apical segments and hyperdynamic contraction of the basal segments, suggesting takotsubo cardiomyopathy (Figure 2, Video 2).

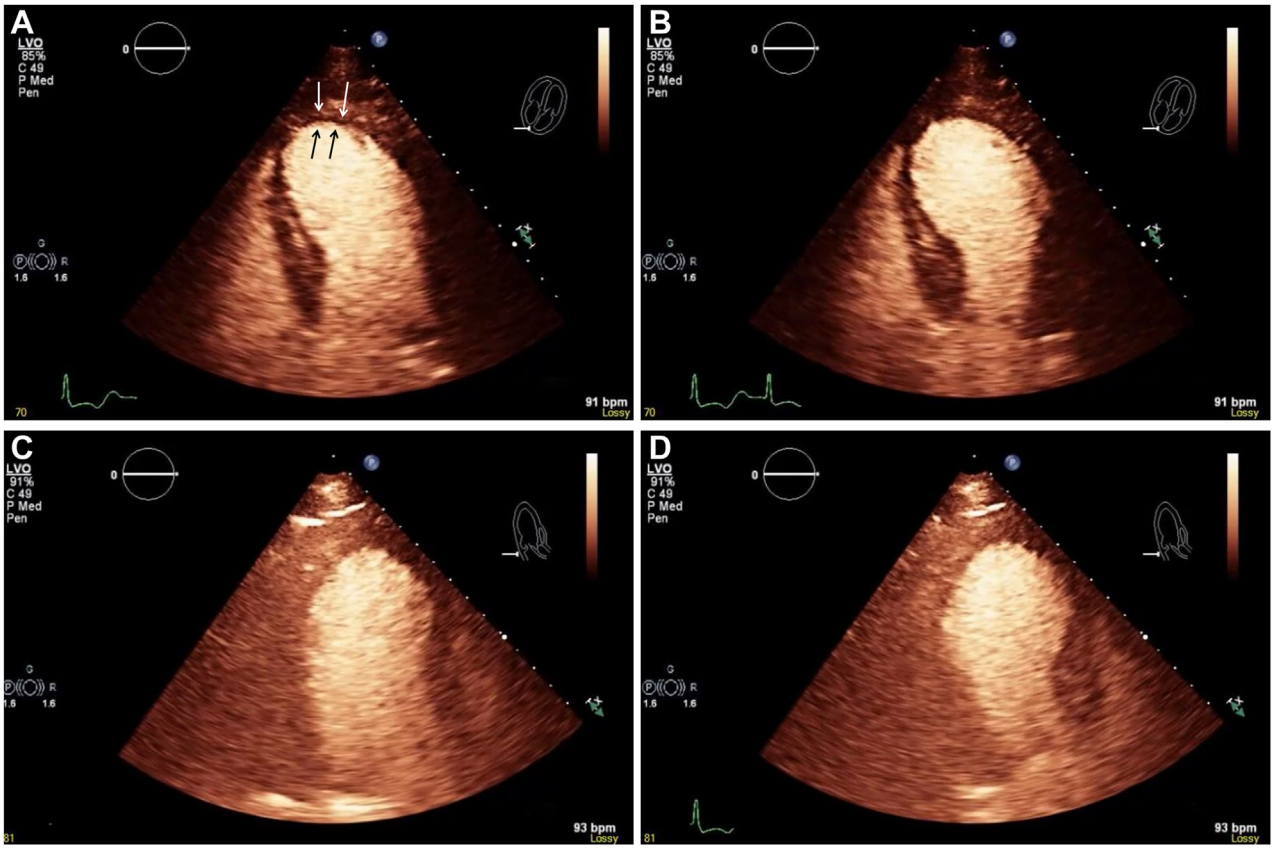

Figure 2 Two-dimensional transthoracic echocardiography, apical four-chamber **(A, B)** and three-chamber **(C, D)** views, with application of ultrasound enhancing agent, during diastole **(A, C)** and systole **(B, D)**, demonstrating left ventricular dysfunction, akinesis of the mid and apical segments, and hyperdynamic contraction of the basal segments. Note the presence of an apical subendocardial perfusion defect (*arrows*).

Thus, norepinephrine was discontinued and phenylephrine was started for persistent hypotension. Subsequent transthoracic echocardiography demonstrated systolic anterior motion (SAM) of the mitral valve and color Doppler flow acceleration across the LVOT (Videos 3 and 4, Figure 3).

With the IABP on 1:1 counterpulsation, pulsed-wave spectral Doppler tracing below the LVOT demonstrated no signal aliasing (Figure 4A), while the signal aliased at the LVOT level (Figure 4B).

The continuous-wave spectral Doppler tracing during IABP counterpulsation had a dagger shape, with a peak gradient of 114 mm Hg (Figure 5A). On the basis of the pulsed-wave spectral Doppler tracing, this gradient was caused by obstruction in the LVOT. To assess the effect of the IABP on the LVOT obstruction, the device was placed on standby, and repeat images were obtained. In the absence of counterpulsation, both mitral valve SAM and LVOT flow acceleration were no longer present (Video 5). The continuous-wave tracing demonstrated a marked decrease in the LVOT gradient to <20 mm Hg (Figure 5B), which was associated with a 15 mm Hg improvement in the mean arterial pressure.

As the IABP counterpulsation was exacerbating the LVOT obstruction and shock, the IABP was removed, leading to hemodynamic improvement and weaning of phenylephrine.

The remainder of the patient's 2-week hospital course was complicated by pneumonia, gastrointestinal bleeding, and bacteremia without endocarditis. Transthoracic echocardiography before discharge showed left ventricular apical akinesis and a peak resting gradient of 30 mm Hg. The patient was subsequently readmitted 3 months later for chest pain. At that time, their left ventricular systolic function had recovered, and they underwent successful myomectomy.

DISCUSSION

This case illustrates dynamic LVOT obstruction in a patient with underlying HCM who developed takotsubo cardiomyopathy. It further demonstrates the utility of echocardiography in demonstrating the detrimental effects of dramatic worsening of the outflow tract obstruction and SAM during IABP counterpulsation.

LVOT obstruction is a hallmark of HCM and is also common in takotsubo cardiomyopathy, with reported rates between 18% and 25% of cases.[1,2] The development of superimposed takotsubo cardiomyopathy in patients with underlying HCM is unusual but has been previously reported.[3,4] This combination can lead to hemodynamic compromise and shock, mainly through increasing LVOT obstruction, but alternative mechanisms, such as a reduction in systemic vascular resistance, have also been postulated.[5-7] Sherrid *et al.*[8] described a case series of 14 patients with HCM who developed cardiogenic shock associated with apical ballooning and high LVOT gradients. Although mimicking classical takotsubo cardiomyopathy, the apical ballooning was thought to reflect the culmination of underlying septal

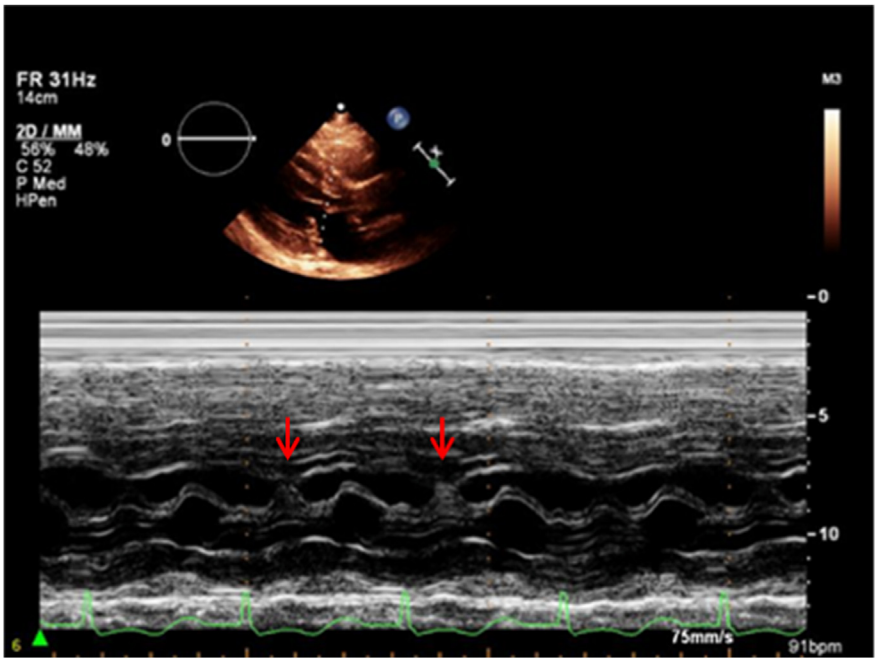

Figure 3 Two-dimensional transthoracic echocardiography, parasternal long-axis view, M-mode, demonstrating SAM of the mitral valve (*arrows*).

hypertrophy, LVOT obstruction, and mitral valve abnormalities. This distinction is potentially important, as clinicians may want to consider HCM-specific therapies in the management of their patients with a takotsubo-like clinical presentation. Indeed, Sherrid *et al.* noted that five patients were treated with urgent septal myectomy, and one underwent alcohol septal ablation.

Although highly symptomatic, our patient did not develop shock until they underwent induction of anesthesia for intubation, when likely a drop in vascular tone contributed to the development of hypotension. The use of norepinephrine and IABP counterpulsation worsened LVOT obstruction. Switching to phenylephrine and removing the IABP resulted in clinical stabilization. In situations in which medical therapy is not adequate and mechanical support is required, VA-ECMO may be preferred over IABP, as it provides circulatory support while increasing afterload.[9]

Echocardiographic imaging and spectral Doppler tracings illustrate the profound sensitivity of the LVOT obstruction to afterload reduction in the unusual clinical setting of takotsubo cardiomyopathy

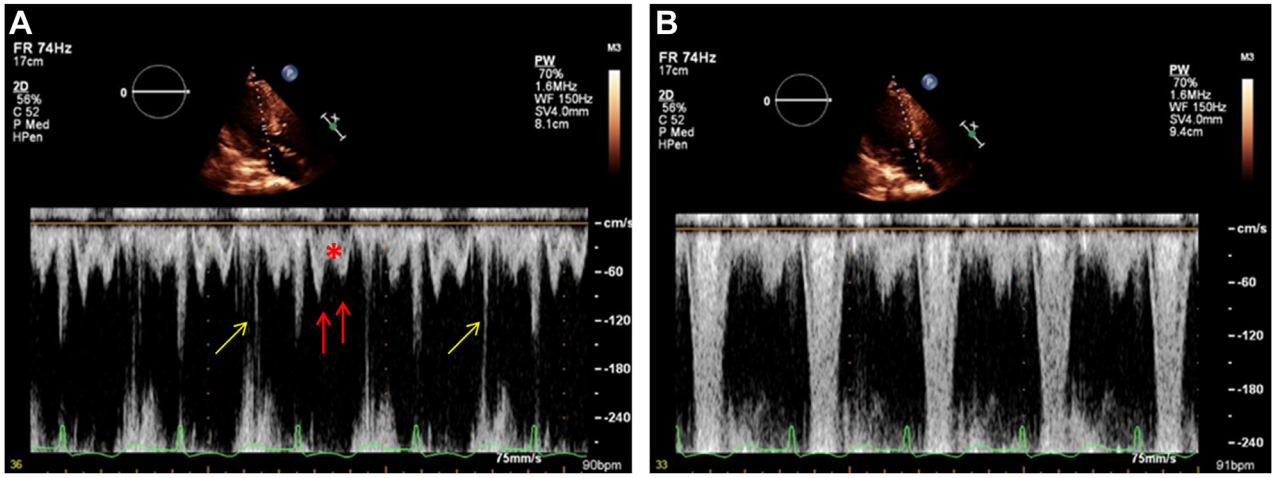

Figure 4 Two-dimensional transthoracic echocardiography, apical three-chamber view, pulsed-wave spectral Doppler tracing below **(A)** and in **(B)** the LVOT during IABP counterpulsation. In **(A)**, note the presence of the echocardiographic equivalent of pulsus bisferiens: two peaks (*red arrows*) in the systolic flow separated by a systolic notch (*red asterisk*). Also note that in the early diastolic filling phase, the elongated anterior mitral leaflet (typical of HCM) is causing a click in the LVOT spectral Doppler signal (*yellow arrows*). In **(B)**, note the presence of signal aliasing resulting from obstruction in the LVOT.

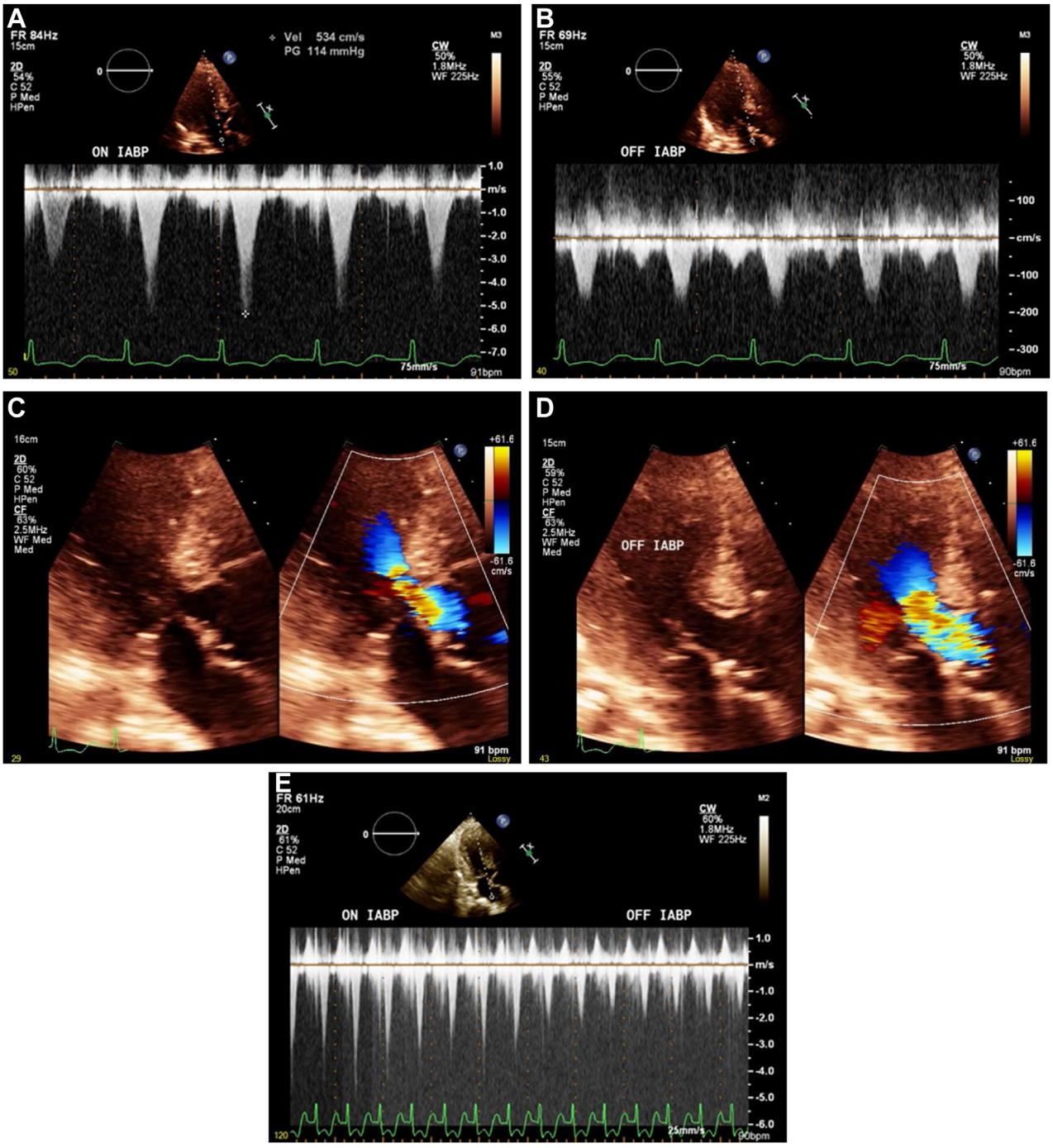

Figure 5 Two-dimensional transthoracic echocardiography, apical three-chamber view, continuous-wave (CW) spectral Doppler tracing across the LVOT with IABP on **(A)** and off **(B)** and color Doppler still frames with IABP on **(C)** and off **(D)**. Note the dagger shape of CW spectral Doppler signal **(A)** associated with a peak gradient of 114 mm Hg and color Doppler aliasing **(C)** during IABP counterpulsation. Note a decrease in the LVOT gradient to <20 mm Hg with the IABP on standby **(B)** and unobstructed LVOT flow **(D)**. **(E)** CW spectral Doppler tracing obtained at a lower sweep speed to demonstrate this phenomenon on a single tracing.

complicating HCM. Both the elevated LVOT flow velocities and SAM improved markedly when the IABP was placed on standby. Conditions that augment left ventricular contractility can worsen LVOT obstruction in takotsubo cardiomyopathy.[2] Similarly, afterload-reducing and preload-reducing interventions may also worsen LVOT obstruction in takotsubo cardiomyopathy.[10] IABPs have also been implicated in worsening LVOT obstruction in takotsubo cardiomyopathy, although clear hemodynamic and echocardiographic

records of this phenomenon are lacking.[11,12] In this case, echocardiography with Doppler uniquely demonstrated the dynamic effects of an IABP in a patient with combined HCM and Takotsubo cardiomyopathy.

CONCLUSION

Patients with takotsubo cardiomyopathy and HCM can have dynamic and severe LVOT obstruction. The use of IABPs and inotropes in such patients with cardiogenic shock should be avoided. Hypotension should be managed with pure α agonists and maintenance of intravascular volume. VA-ECMO may be preferred in cases of refractory shock.

ETHICS STATEMENT

The authors declare that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans.

CONSENT STATEMENT

The authors declare that since this was a non-interventional, retrospective, observational study utilizing deidentified data, informed consent was not required from the patient under an IRB exemption status.

FUNDING STATEMENT

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DISCLOSURE STATEMENT

The authors report no conflict of interest.

SUPPLEMENTARY DATA

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