Two Barricades in a Row Mixed Lesion of Dynamic Left Ventricular Outflow Tract Obstruction and Aortic Stenosis: Finding the Culprit for Decision Making

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Abstract

Concurrent lesions of dynamic left ventricular outflow tract obstruction (DLVOTO) with aortic stenosis pose a challenge in the measurement of the pressure gradient and severity of each lesion. Determining the true culprit lesion is difficult and challenging. The establishment of true culprit lesion is crucial in deciding the future course of action. We present two cases of concurrent DLVOTO and aortic stenosis. Although the composition of lesions is similar, the severity of each lesion was different and described a variety of technical problems. Finding the culprit through the shape of the stenotic jet from the continuous wave Doppler as well as other different technical approaches is the critical point of this case report. The first patient showed nonsignificant DLVOTO with severe aortic stenosis in which transthoracic echocardiography (TTE) alone was sufficient to find the culprit. Meanwhile, the second patient concluded to have significant DLVOTO with moderate aortic stenosis based on TTE and transesophageal echocardiography examination data. Jet morphology from Doppler examination is a crucial finding to differentiate DLVOTO with aortic stenosis, along with other parameters that might help find the dominant lesion. Multiple modalities with several tailor-made technical considerations might be needed to establish a culprit lesion.

Keywords: Aortic stenosis, continuous wave Doppler, dynamic left ventricular outflow tract obstruction, mixed lesions

INTRODUCTION

The modern echocardiography examinations rely heavily on the Doppler principle. In this principle, the velocity of blood flow can be measured by the transducers by assessing the movement of red blood cells from one point to another.[1] Currently, two modalities in echocardiography rely on this principle, namely, continuous-wave Doppler (CWD) and pulsed wave Doppler (PWD). PWD is generally used for velocity sampling on one location; however, its use is limited by the Nyquist limit. CWD is used for high-velocity measurement in cases where the source of velocity cannot be determined with the trade-off of the ability to record high-velocity gradient.[2] In general, stenotic lesion occurs in only one location; hence, the inability of CWD to determine the source of velocity is irrelevant [Figure 1, upper Figure].[3] Challenges are encountered when there is more than one stenotic lesion along the ultrasound beam, such as in a patient with a concomitant left ventricular outflow tract obstruction (LVOTO) and aortic stenosis. In this particular setting, it is challenging to find the culprit lesion with the highest pressure gradient.

CWD is useful to differentiate between dynamic and fixed stenosis. It is also an effective way to distinguish the pressure gradient between lesions.[4] Dynamic stenosis, such as in the case of dynamic LVOTO, will show a dagger-like pattern, whereas fixed stenosis such as aortic stenosis will show a parabolic pattern on CWD mode [Figure 2].[5] In clinical practice, sometimes, it is difficult to distinguish between these patterns of flow.

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Establishing the culprit lesion in the face of multiple outflow obstructive lesions is essential in determining the future course of treatment. In this study, we present two cases of double stenotic lesions of the left ventricular outflow tract. We aim to delineate the challenges and steps in finding this culprit lesion based on these two cases.

**Case Reports**

**Case 1**
A 71-year-old female was referred to our facility for further management. She was previously diagnosed with hypertrophic obstructive cardiomyopathy (HOCM). The patient complained of dyspnea on effort and a history of loss of consciousness in 2008. Electrocardiography examination showed left ventricular hypertrophy with strain pattern, signifying pressure overload. Echocardiography examination was done. Thickened interventricular septum with turbulence at LVOT and bicuspid aortic morphology with restricted opening suggestive of aortic stenosis was observable on the parasternal long-axis view (PLAX) [Figure 3a and d and g]. M-mode evaluation showed the systolic anterior motion (SAM) of the AML [Figure 3b]. A thickened interventricular septum extending from the basal to the apical region was observable on the four-chamber view [Figure 3c]. Severe mitral valve regurgitation and positive pulmonary reversal flow were seen [Figure 3a and d, respectively]. The pressure gradient of the aortic valve was 75.5 mmHg, and aortic valve area (AVA) was 0.82 cm² evaluated using continuity equation and 0.94 cm² using planimetry [Figure 3g and h respectively]; these findings are consistent with severe aortic stenosis. Evaluation of dynamic LV gradient was measured using PWD to locate the location of the highest gradient, showing a gradient of 25 mmHg at the LVOT area [Figure 3i].

Based on the findings above, the patient was diagnosed with a nonsignificant dynamic LVOT obstruction with severe aortic stenosis and severe mitral regurgitation.

**Case 2**
A 63-year-old male presented to our facility seeking a second opinion of his condition. He was previously diagnosed with a valvular condition at another hospital and treated with bisoprolol 2.5 mg once daily. The patient reported episodes of dyspnea on effort. Electrocardiography showed left ventricular hypertrophy with strain pattern, indicating pressure overload. Coronary angiography revealed triple vessel disease.

Echocardiography was done in this patient. On PLAX, concentric left ventricular hypertrophy with interventricular septum thickness of 22 mm was seen. Aortic calcification with some degree of the restricted opening was also seen [Figure 4a]. SAM was observable on M-mode examination of the mitral valve leaflet, confirming a dynamic LVOT obstruction [Figure 4c]. From the four-chamber view, a prominent ventricular septal bulge at the level of the basal septum was seen [Figure 4d]. CWD measurement in the five-chamber view generates the highest pressure gradient of 110 mmHg. An attempt to measure the aortic valve pressure gradient yielded a pressure gradient of 19 mmHg [Figure 4f]. Aortic area evaluation using planimetry was not done due to poor visualization of the aortic valve. Transesophageal echocardiography (TEE) was done and three-dimensional (3D) planimetry of aortic valve showed AVA of 1.2 cm² [Figure 4g], indicating moderate aortic stenosis. Measurement of LVOT pressure gradient was also done using TEE [mid esophageal LVOT view at 120°, Figure 4h], showing a dagger-like pattern in CWD, indicating a dynamic LVOTO.

Based on the findings, this patient was diagnosed with significant dynamic LVOT obstruction with severe aortic stenosis.

**Discussion**
The diagnosis of primary “culprit” lesion in a patient with multiple obstructive lesions, such as aortic stenosis and LVOTO, is crucial to determine a therapeutic approach. Unfortunately, this evaluation of multiple obstructive lesions might be challenging. Additional parameters and modalities might be needed.

The measurement of two stenotic lesions in one line of measurement is challenging due to the caveat of the CWD approach which does not localize the source of obstruction. On the other hand, PWD may have the ability to pinpoint the
location of the obstruction, but inaccuracy in interpretation is a major concern once the velocity of the stenotic jet has surpassed the Nyquist limit.\(^1,6\) Furthermore, finding the dagger-shaped pattern of CWD is sometimes difficult for the case of two consecutive stenotic lesions in a row\(^7\) [Figures 3 and 4].

When discussing the concept of the stenotic lesion, velocity, and pressure gradient, it is crucial to take the continuity equation into consideration [Figure 5], which stated that the velocity is proportionally related to the pressure gradient.\(^6\)

Prior to the widespread use of Doppler quantification for the evaluation of aortic stenosis, an invasive method using Gorlin formula was used as a standard for assessing the severity of aortic stenosis. As the Doppler quantification becomes more widespread, this invasive approach is not routinely used anymore, and the Gorlin assessment of AVA relies on the following equation:\(^8\)

\[
\text{Gorlin AVA} = \frac{SV}{44.3 \times \sqrt{\Delta P_{\text{mean}}}}
\]

Noninvasive assessment, however, comes with the caveat of less accuracy, especially in patients with severely calcified cusps and in upper septal hypertrophy, due to the difficulty of determining LVOT velocity time integral (VTI) and LVOT diameter.\(^9\)

From the echocardiographic point of view, prompt assessment of anatomical aspects using echocardiography is crucial to evaluate the presence of aortic stenosis. The number of the aortic cusp, the extent of calcification, and restriction in cusp movement can help clinicians establish the presence of aortic stenosis in echocardiographic view. These considerations will be useful in building treatment strategy if the presence of aortic stenosis is considered to be significant.\(^10-12\) For instance, patients with bicuspid aortic valve stenosis have poor clinical outcomes for TAVR procedure due to the noncircular annulus and carries postprocedural perivalvular risk and stroke risk.\(^13\) In cases of dynamic LVOT obstruction, we may have to explore several possible causes other than hypertrophic cardiomyopathies (HOCM), such as catecholamine excess, exercise overload, anorexia, dehydration, concentric LV hypertrophy, Takotsubo, amyloidosis, and anemia.\(^14\)

In both cases presented in this study, dynamic LVOT obstruction and aortic stenosis were present but in different
severity. In the first case, the morphology of aortic valve, calcification, and the restricted motion of the cusps shows that significant stenosis of the aortic valve is present. This assumption was supported by the result of Doppler evaluation, which shows a parabola-shaped curve consistent with severe aortic stenosis. The severity of dynamic LVOTO (DLVOTO) was evaluated using PWD instead of CWD to evaluate the exact location of the dynamic gradient because the maximum gradient that is measured has not reached the Nyquist limit.

By applying this concept to both of our cases, we can determine the culprit lesion in each case.

In the first case, performing continuous wave, Doppler will show the highest gradient. The reason that we concluded that V2 was the culprit lesion was that PWD can still be measured in V1 [Figure 6]. The AVA predicted by pressure gradient measured from CWD was equivalent to the AVA calculated from planimetry, which both indicate severe aortic stenosis [Figure 3f and 3g]. In the second patient, we were not able to assess the lesion using PWD due to the velocity surpassing the Nyquist limit. Therefore, we performed measurement using CWD through transthoracic echocardiography (TTE), which clearly shows the highest velocity [Figure 7].

Meanwhile, in the second case, determining the culprit lesion is more challenging. The morphology of the aortic valve shows a great likelihood of significant aortic stenosis, but the parameter to evaluate the severity of stenosis might not be reliable. Evaluation of AVA planimetry by TTE, for example, could not be done due to poor echo image quality. Furthermore, the evaluation of AVA by the continuity equation might be not accurate because it would be difficult to measure LVOT VTI in a patient with a high dynamic gradient at LVOT. Evaluation of AVA by planimetry was done using 3D TEE, which shows moderate aortic stenosis (AVA 1.2 cm²). Evaluation of dynamic gradient severity, in this case, was done by TTE, which shows a dagger-shaped pattern. The use of TEE in this patient, however, is still beneficial to differentiate between dynamic and fixed gradient based on the wave morphology.

The measurement of AVA using 2D planimetry was not feasible due to the suboptimal visualization [Figure 3f]. Therefore, the measurement was done using TEE. We were able to capture the waveform of dynamic LVOT gradient using CWD at mid position view at 120° [Figure 7], which shows a dagger-shaped pressure gradient, indicating a dynamic LVOT gradient [Figure 4h]. The pressure gradient obtained through TTE was matched with the pressure gradient measured by TEE [Figure 3e and 3h]; consistency was observed, signifying LVOT obstruction. Furthermore, to strengthen the findings, measurement of 3D AVA planimetry [Figure 3g] was done and showed moderate stenosis (AVA planimetry 1.2 cm²).

Based on the echocardiography findings, Case 1 was found to suffer from severe aortic stenosis with nonsignificant LVOT obstruction and severe mitral regurgitation, whereas Case 2 suffered from moderate aortic stenosis but with significant LVOT obstruction. Another method that might be used to evaluate aortic stenosis severity and its prognosis is using the ejection fraction/velocity ratio (EFVR). A study by Antonini-Canterin et al. discussed this approach and had been using the EFVR (LVEF = Left ventricle ejection fraction; \( V^2 \) = peak velocity of aortic stenosis):

\[
\text{EFVR} = \frac{\text{LVEF}}{4 \times V^2}
\]

As a function-corrected index of aortic stenosis severity which is useful for risk stratification in asymptomatic moderate-to-severe aortic stenosis to evaluate those who are candidates for elective aortic valve replacement. If the result of this equation is \( \leq 0.9 \), an increase in mortality risk is anticipated and serves as the need for aortic valve replacement (hazard ratio: 2.14, 95% confidence interval:...
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Resume
We presented two cases of concurrent DLVOTO and aortic stenosis. We established different courses of action on both cases using the echocardiographic approach in determining the culprit obstructive lesion. One case was prioritized for aortic valve replacement due to the severe aortic stenosis, whereas the other was prioritized for myocardial septal reduction due to the significant LVOT obstruction. However, echocardiographic approach might have to be tailored to a case-by-case basis to anticipate the anatomical difference between the patients.

Clinical bottom-line
These two cases proved that finding the culprit lesion based on the shape of CW Doppler waveform was very challenging; however, finding the dagger-shaped jet from CWD is paramount for determining the nature of LVOT obstruction. Several studies with similar cases also mentioned this difficulty.[7,10] Several additional steps might have to be taken to reveal the culprit lesion.

Declaration of patient consent
The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest
There are no conflicts of interest.

References
1. Anderson B. Echocardiography: The Normal Examination of Echocardiographic Measurements. Oxford: Blackwell Publishing; 2002. p. 251.
2. Miller FA Jr. The Integration of Doppler Ultrasound With Two-Dimensional Echocardiography and the Noninvasive Cardiac Hemodynamic Revolution of the 1980s. J Am Soc Echocardiogr. 2018;31:1353-65.
3. Baumgartner H, Hung J, Bermejo J, Chambers JB, Edvardsen T, Goldstein S, et al. Recommendations on the Echocardiographic Assessment of Aortic Valve Stenosis: A Focused Update from the European Association of Cardiovascular Imaging and the American Society of Echocardiography. J Am Soc Echocardiogr 2017;30:372-92.
4. Mashari A, Mahmood F. Fixed versus dynamic left ventricular outflow tract obstruction: Res ipsa loquitur. J Thorac Cardiovasc Surg 2016;151:885-6.
5. Alrammah H, Ghazal S. Significant left ventricular outflow tract obstruction secondary to systolic anterior motion in a patient without hypertrophic cardiomyopathy: An echocardiographic study [Internet]. Journal of the Saudi Heart Association 2018;30:336-9. Doi: http://dx.doi.org/10.1016/j.jsha.2018.07.001.
6. Anavekar NS, Oh JK. Doppler echocardiography: A contemporary review [Internet]. Journal of Cardiology 2009;54:347-58. Doi: http://dx.doi.org/10.1016/j.jjcc.2009.10.001
7. Ishimura M, Takayama M, Saji M, Takamisawa I, Umemura J, Sumiyoshi T, et al. A case of hypertrophic obstructive cardiomyopathy with aortic stenosis. J Cardiol Cases 2014;9:129-33.
8. Burwash IG, Thomas DD, Sadahiro M, Pearlman AS, Verrier ED, Thomas R, et al. Dependence of Gorlin formula and continuity equation valve areas on transvalvular volume flow rate in valvular aortic stenosis. Circulation 1994;89:827-35.
9. Antonini-Canterin F, Pavan D, Burelli C, Cassin M, Cervesato E, Nicolosi GL. Validation of the ejection fraction-velocity ratio: a new simplified “function-corrected” index for assessing aortic stenosis severity. Am J Cardiol 2000;15;86:427-33.
10. Baumgartner H, Hung J, Bermejo J, Chambers JB, Evangelista A, Griffin BP, et al. Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. Eur J Echocardiogr 2009;10:1-25.
11. Abramowitz Yigal, Jilaihawi Hasan, Chakravarty Tarun, Mack Michael J., Makkar Raj R. Porcelain Aorta. Circulation. 2015;131:827-36.
12. Kolte D, Vlahakes GJ, Palacios IF, Sakhija R, Passeri JJ, Inglessis I, et al. Transcatheter Versus Surgical Aortic Valve Replacement in Low-Risk Patients. J Am Coll Cardiol 2019;74:1532-40.
13. TAVR for Bicuspid Aortic Valves: Is Surgery Still the Gold Standard?
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- American College of Cardiology [Internet]. American College of Cardiology. Available from: https://www.acc.org/latest-in-cardiology/articles/2019/04/17/07/14/tavr-for-bicuspid-aortic-valves. [cited 2019 Dec 22].

14. Cha JJ, Chung H, Yoon YW, Yoon JH, Kim J-Y, Min P-K, et al. Diverse geometric changes related to dynamic left ventricular outflow tract obstruction without overt hypertrophic cardiomyopathy. Cardiovasc Ultrasound 2014;12:23.

15. Antonini-Canterin F, Di Nora C, Cervesato E, Zito C, Carerj S, Ravasel A, et al. Value of ejection fraction/velocity ratio in the prognostic stratification of patients with asymptomatic aortic valve stenosis. Echocardiography 2018;35:1909-14.

16. Mancuso AJ, Clark J, Mahmood F. Left Ventricular Outflow Tract Obstruction: Is It the Valve or Something Else? [Internet]. Journal of Cardiothoracic and Vascular Anesthesia 2014; 28:848-9. Doi: http://dx.doi.org/10.1053/j.jvca.2014.02.01.