Case Report

# Analysis of Post-Systolic Shortening, Myocardial Strain, and Arterial Flow to Assess Myocardial Ischemia during Stress Echocardiography

***Análise do Encurtamento Pós-Sistólico, do Strain Miocárdico e do Fluxo Arterial na Avaliação de Isquemia Miocárdica Durante o Ecocardiograma sob Estresse***

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## Introduction

In the past four decades, stress echocardiography has been used for accurately diagnosing coronary artery disease (CAD).[1] However, other techniques, including assessment of flow velocities in the internal thoracic artery (ITA) and anterior descending coronary artery (ADA), have also been adopted for evaluation of myocardial ischemia. Systolic flow velocity is higher than diastolic flow velocity in the ITA. However, the latter increases after the ITA anastomoses into the left coronary artery, and the flow resembles that of patent ADA.[2]

During stress echocardiography (SE) with dobutamine, dipyridamole, or adenosine, diastolic flow velocity increased in the patent ADA, and the coronary flow reserve (CFR) was calculated non-invasively by dividing the peak diastolic velocity during stress by the baseline velocity. Adequate CFR (≥2) can be obtained prior to submaximal heart rate (HR), to improve prognosis in patients with confirmed or potential CAD.[3-5]

The global longitudinal strain (GLS) of the left ventricle (LV) can be obtained during stress or at rest, and its normal value is –20% ± –2%. Impaired GLS, although not specific, is critical for the diagnosis and prognosis of myocardial ischemia, condition also observed in the evaluation of ischemia by the Post-Systolic Shortening Index (EPS),when it has values greater than 20%.[6-9]

## Case report

A 71-year-old woman presenting with hypertension and dyslipidemia was revascularized 12 years ago, and her left ITA anastomosed into the ADA. The patient was receiving nitrate, angiotensin-converting enzyme inhibitor, aspirin, and beta-blockers. Approximately two months prior to the diagnosis, she presented with atypical chest pain on exertion and was referred to SE for assessment of myocardial ischemia.

## Keywords

*Myocardial strain; Internal thoracic artery; Stress echocardiography.*

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### Baseline evaluation

During the assessment at rest, systolic flow velocity was higher than diastolic flow velocity in the right ITA (Figure 1A), whereas in the anastomosed left ITA, there was only systolic flow, and the flow velocity was low (Figure 1B). However, diastolic flow was higher than the systolic flow in the ADA (Figure 1C). The baseline GLS in the LV decreased by 16%, indicating segmental impairment, but was less pronounced in the ADA territory (Figure 2A). Baseline PSI was abnormal in the inferior LV wall (Figure 2B).

### Stress test

SE revealed that the patient had typical angina and contractile abnormalities that were compatible with ischemia in the inferior LV wall, and were more evident during the recovery phase (Videos 1 and 2). Diastolic flow velocity increased significantly in the ADA, and adequate CFR was achieved at an HR of 88 bpm (60% of the maximum HR) (Figure 1D).

There was a further reduction in the GLS (mainly in the inferior and posterior walls) and regional LV deformation in the ADA territory (Figure 2C). PSI was abnormal (>20%) in a long segment of the LV but normal in the ADA (Figure 2D).

### Hemodynamic study

Coronary angiography showed complete stenosis of the middle third of the left ITA and the right proximal coronary artery, which was perfused by multiple collateral vessels. The circumflex artery and its marginal branch were clearly observed and partially occluded. The degree of stenosis of the ADA was approximately 50%. The patient underwent angioplasty in the circumflex artery and marginal branch, and a stent was placed in the former.

### Status after hemodynamic intervention

Approximately two months after the hemodynamic intervention, the resting echocardiogram showed normal GLS (–20.6%) and a minor abnormality in the anterolateral wall (Figure 2E), whereas PSI was normal (Figure 2F).

Despite being asymptomatic, the patient was referred to SE after six months because previous angiography showed anatomical impairment of the ADA and the right coronary artery, and another examination revealed submaximal HR. SE showed that the patient achieved maximum HR, with no symptoms or contractile abnormalities (Videos 3 and 4). Adequate CFR was obtained at 60% of maximum HR.

# Case Report

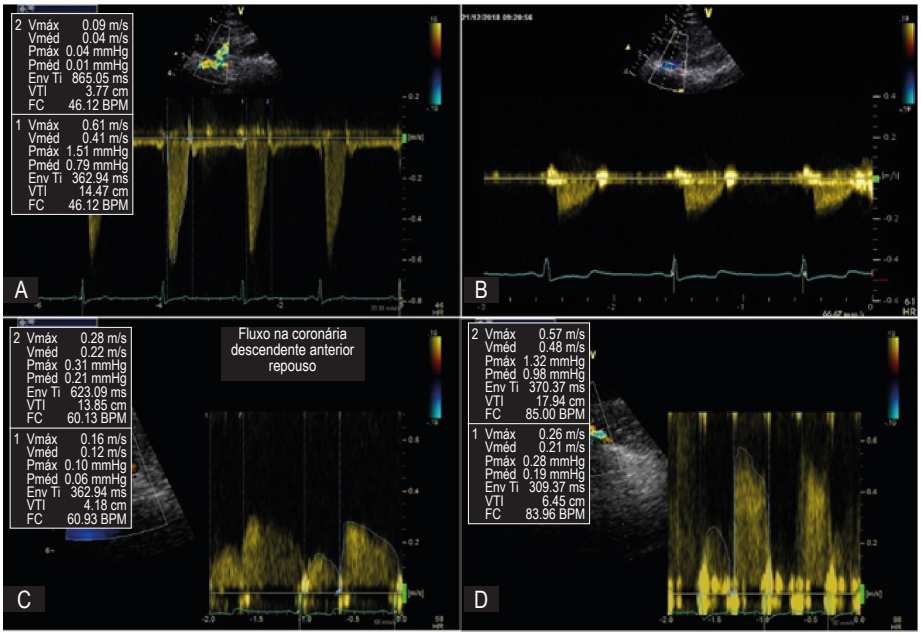



**Figure 1 –** *(A) Right internal thoracic artery (ITA) in situ shows a normal flow pattern with high systolic velocity and low diastolic velocity. (B) Left ITA anastomosed into the left anterior descending coronary artery (ADA) with only systolic flow and low flow velocity, which is compatible with the ITA occlusion. (C) ADA has a high diastolic flow velocity at rest. (D) Stress echocardiography revealed that diastolic flow velocity in the ADA doubles at 60% of the maximum predicted HR.*

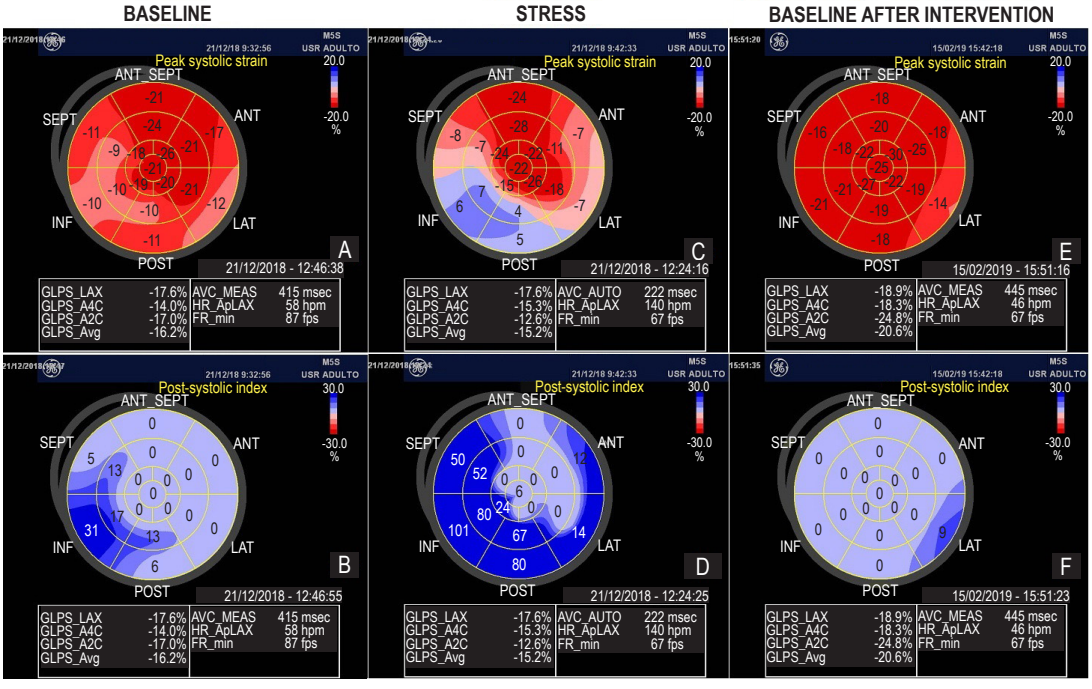
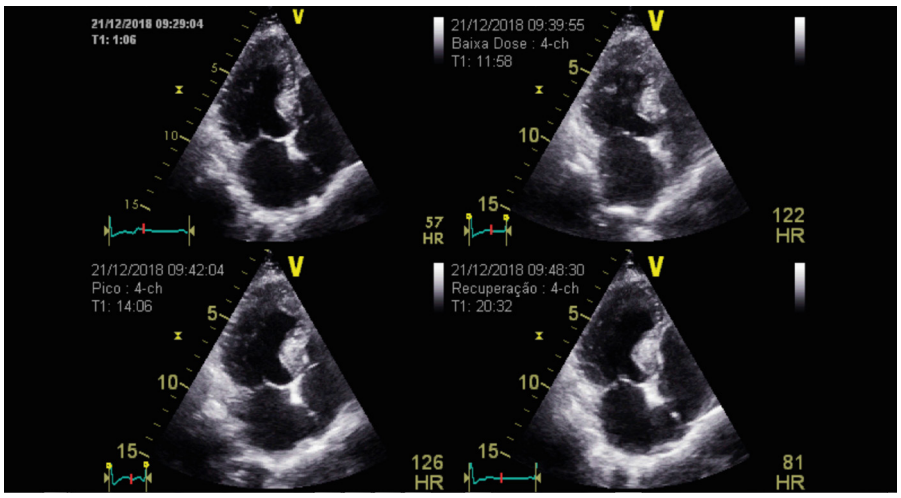
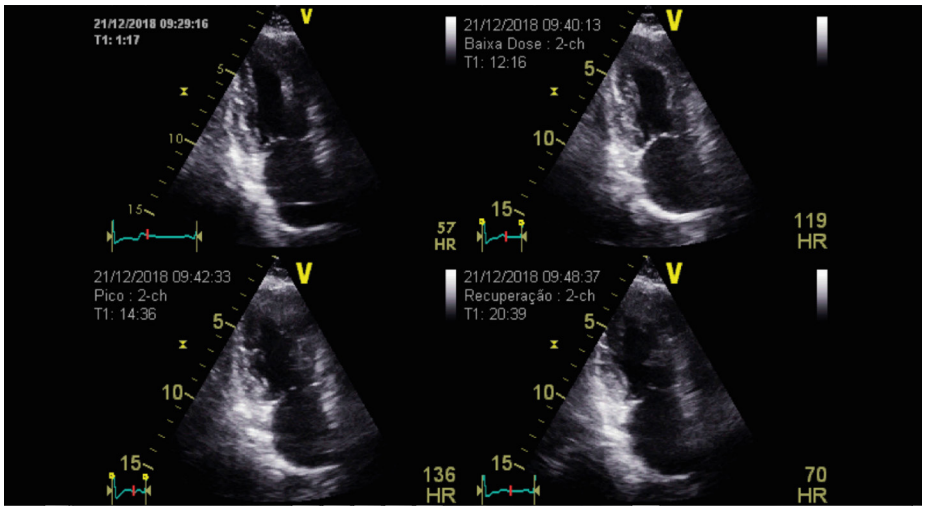



**Figure 2 –** *(A) Global longitudinal strain (GLS) is abnormal at baseline (–16%). The left ventricle is diffusely impaired, but the anterior descending coronary artery (ADA) territory is partially preserved. (B) The post-systolic index was abnormal (>20%) in the inferior wall. (C) During stress echocardiography, GLS showed reduced contractile function, and (D) the post-systolic index showed that the impairment of contractile function was more pronounced and extensive, whereas the ADA territory was fully preserved. Hemodynamic intervention normalized GLS (–20.6%) and all segments to post-systolic shortening.*




**Video 1 –** *Before hemodynamic intervention. In the 4-chamber apical record, the left ventricle shows normal contractility during dobutamine stress echocardiography at submaximal heart rate.*




**Video 2 –** *Before hemodynamic intervention. In the 2-chamber apical record during dobutamine stress echocardiography, the left ventricle presents a contractile abnormality compatible with ischemia in the inferior wall (below left) in submaximal heart rate. Ischemia is most evident in the recovery phase (bottom right).*

## Discussion

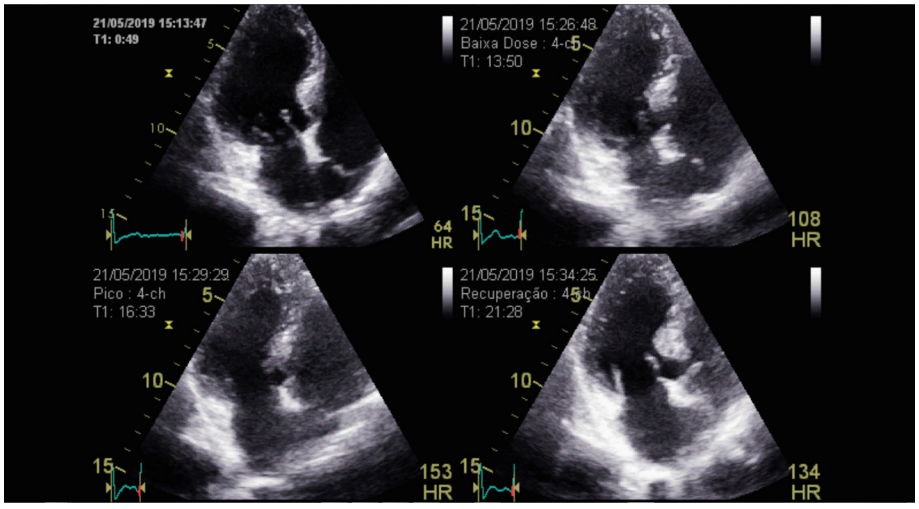
In this case report, the adopted echocardiographic techniques were complementary and critical for evaluation of the complex CAD.

The flow velocity in the right ITA was compatible with a native artery, whereas the velocity in the anastomosed left ITA was compatible with ITA graft occlusion. The ADA was partially occluded; however, adequate and early CFR indicated that the functional status of this vessel was good, demonstrating that the conservative treatment of this coronary artery was successful, which corroborated with previous studies.[5,10]

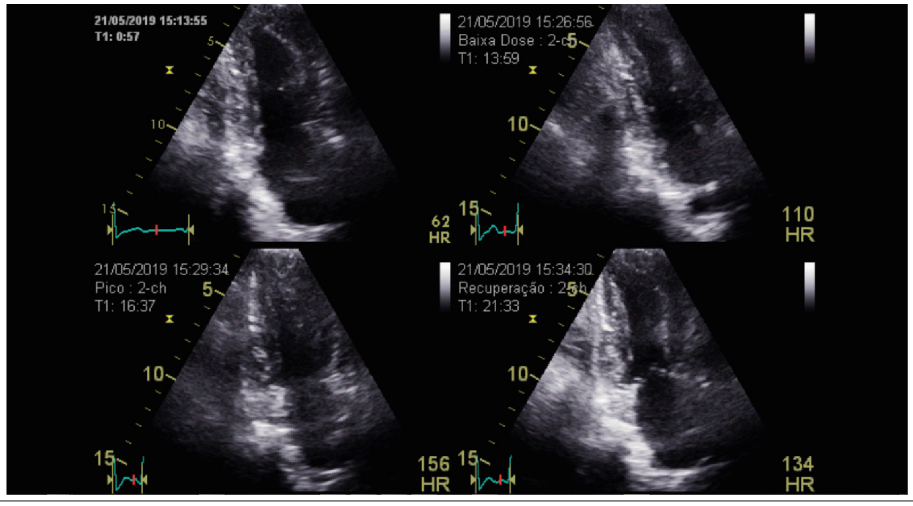
Impaired GLS and PSI might be strongly correlated with the presence of myocardial ischemia, but this result is not specific to CAD. Nevertheless, the presence of abnormal patterns during examination at rest should be considered. In addition, the appearance of abnormality or worsening of GLS or PSI, during the use of stressors, improves the prognosis of myocardial ischemia.[6,8,9]

During the first SE at submaximal HR, ischemia was more evident in the recovery phase and involved only the inferior wall. However, GLS and PSI revealed the larger extent of ischemia, and these results were in agreement with the hemodynamic findings.

It is noteworthy that, after the intervention, there was a significant improvement in segmental GLS and normalization of GLS at rest and complete normalization of PSI in all segments. These improvements were corroborated




**Video 3 –** *After hemodynamic intervention. In the 4-chamber apical record, the left ventricle presents normal contractility during dobutamine stress echocardiography at maximum heart rate.*




**Video 4 –** *After hemodynamic intervention. In the 2-chamber apical record, the left ventricle presents normal contractility during dobutamine stress echocardiography at maximum heart rate.*

by SE at maximum HR, which confirmed the absence of ischemia, as the myocardial contractility was normal and the symptoms were absent.

We believe that the techniques used in our case were the best approach. Anastomosed ITA may have occluded because of an intraoperative accident or flow competition with the ADA. However, this complication was not addressed in this study. Although the left ITA was occluded and the ADA was partially occluded, the results indicated that the conservative approach was adequate for the ADA.

The right coronary artery territory was irrigated by multiple collateral vessels but was ischemic. However, ischemia was reduced in the left coronary system after the intervention, suggesting that this approach increased the blood supply and significantly increased the blood flow in the collateral vessels that perfused this territory.

Compared to hemodynamic findings, PSI and GLS were more associated with the extent of ischemia than SE, and the CFR of the ADA indicated that the function of this vessel was preserved. A limitation in the use of GLS or PSI is the low quality of the echocardiographic window, especially during SE. However, we did not encounter this limitation in our study.

## Conclusion

The use of different echocardiographic techniques improves the diagnosis and management of myocardial ischemia.

## Author contribution

Abreu JS and Abreu MEB conceived and designed the study; Abreu JS, Abreu MEB, Pinheiro TCD, and Lima AAG collected the data; Abreu JS, Abreu MEB, Lima AAG, and Machado IS analyzed and interpreted the data; Abreu JS, Freire RAP, and Santos LPG wrote the manuscript; Abreu JS and Abreu MEB critically revised the manuscript for intellectual content.

## Conflict of interest

The authors have declared that they have no conflict of interest.

## References

1. Pellikka PA, Nagueh SF, Elhendy AA, Kuehl CA, Sawada SG. Recomendações da Sociedade Americana de Ecocardiografia para a realização, interpretação e aplicação da Ecocardiografia de Estresse. Rev Bras Cardiol: Imagem Cardiovasc [Internet]. 2013 [cited Feb 10, 2020];26(4):242-26. http://departamentos.cardiol.br/dic/publicacoes/revistadic/revista/2013/portugues/Revista04/03-especial.pdf
2. Abreu JS, Tsutsui JM, Falcão SN, Feitosa JA, Rocha EA, Oliveira IM, et al. The impact of ligation of proximal side branches on blood flow and functional status of the internal thoracic artery in coronary anastomosis. Echocardiography. 2016;33(11):1656-64.
3. Meimoun P, Sayah S, Tcheuffa JC, Benali T, Luycx-Bore A, Levy F, et al. Transthoracic coronary flow velocity reserve assessment: comparison between adenosine and dobutamine. J Am Soc Echocardiogr. 2006;19(10):1220-8.
4. Forte EH, Rousse MG, Lowenstein JA. Target heart rate to determine the normal value of coronary flow reserve during dobutamine stress echocardiography. Cardiovascular Ultrasound. 2011;9:10.
5. Abreu JS, Rocha EA, Machado IS, Parahyba IO, Rocha TB, Paes FJ, et al. Valor prognóstico da reserva de fluxo coronariano obtida durante o ecocardiograma sob estresse com dobutamina e sua correlação com a frequência cardíaca alvo. Arq Bras Cardiol. 2017;108(5):417-26.
6. Collier P, Phelan D, Klein A. A test in context: myocardial strain measured by speckle-tracking echocardiography. J Am Coll Cardiol. 2017;69(8):1043-56.
7. Voigt JU, Lindenmeier G, Exner B, Regenfus M, Werner D, Reulbach U, et al. Incidence and characteristics of segmental postsystolic longitudinal shortening in normal, acutely ischemic, and scarred myocardium. J Am Soc Echocardiogr. 2003;16(5):415-23.
8. Asanuma T, Nakatani S. Myocardial ischaemia and post-systolic shortening. Heart. 2015;101(7):509-16.
9. Brainin P, Hoffmann S, Fritz-Hansen T, Olsen FJ, Jensen JS, Biering-Sørensen T. Usefulness of postsystolic shortening to diagnose coronary artery disease and predict future cardiovascular events in stable angina pectoris. J Am Soc Echocardiogr. 2018;31(8):870-9. e3.
10. D'Andrea A, Severino S, Mita C, Riegler L, Cocchia R, Gravino R, et al. Clinical outcome in patients with intermediate stenosis of left anterior descending coronary artery after deferral of revascularization on the basis of noninvasive coronary flow reserve measurement. Echocardiography. 2009;26(4):431-40.