My approach of Diastolic Stress Echocardiography

Como Eu Faço Ecocardiograma de Estresse Diastólico

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Introduction

Doppler echocardiography (DE) plays an essential role in the evaluation at rest on all patients with symptoms of heart failure (HF).[1,2] However, patients with HF and preserved ejection fraction (HFpEF) may have dyspnea during exercise only, with hemodynamic profile, cardiac output (CO) and left ventricular filling pressure (LVFP) at rest similar to healthy individuals with normal diastolic function.[1,2] Evaluation at rest may be insufficient in these patients, justifying an exam that can also do an evaluation with exercise, confirming or ruling out increased LVFP.[3,4]

Diastolic stress echocardiography

Normal response to exercise is a several fold increase in CO without increasing LVFP, especially by improving relaxation with more efficient diastole suction. In the presence of diastolic dysfunction, myocardial relaxation is impaired, becoming more evident with exercise, with abnormal relaxation and early diastole suction not suitable for normal filling. The result is an inadequate increase in CO with increased LVFP.

Evaluation of diastolic function parameters using diastolic stress echocardiography (DSE) during exercise shows these hemodynamic abnormalities.[5,6] The most studied and validated parameters are the ratio of mitral flow E-wave velocity to early diastolic velocity (e’) on mitral annulus tissue Doppler, and peak tricuspid regurgitation velocity (PTRV) for the estimation of pulmonary wedge pressure (PWP) and pulmonary artery systolic pressure (PASP), respectively, rest and exercise.[7] In the presence of normal relaxation, there is a proportional increase in E and e’ velocities during exercise, maintaining the ratio unchanged.[8] In individuals with myocardial disease and abnormal relaxation, there is no e’ increase such as in E velocity, which also goes up due to increased left atrial (LA) pressure, with an expected increase in E/e’ ratio. Studies with invasive hemodynamic correlation have shown that evaluation of E/e’ ratio in exercise is very useful when it is <10 (septal) to rule out increased LVFP and >14 (mean) to suggest increased LVFP.[5,6,7] Estimating PASP during exercise is also very useful, as the presence of exercise-induced pulmonary hypertension is associated with adverse cardiac events and higher mortality rates.[9]

Myocardial ischemia may cause diastolic dysfunction with increased LVFP and dyspnea. Patients with known or suspected coronary artery disease referred for stress echocardiography for ischemia investigation benefit from the addition of diastolic function evaluation, where prognostic information related to functional capacity, clinical outcomes and mortality can be obtained.[10,11]

With a larger number of publications demonstrating feasibility, hemodynamic validation and diagnostic implications, diastolic function and chronic HF evaluation guidelines have been recommending the use of DSE in the clinical suspicion of HFpEF due to unexplained dyspnea on exertion with grade I diastolic dysfunction at rest.[3,4,12]

Protocols used in the diagnosis of HF_pEF with DSE

DSE can be performed on the bicycle or treadmill, and the choice will depend on the site availability and service experience. Pharmacological stress echocardiography is not recommended.[3,4] Of the two types, supine bicycle exercise is the most recommended for evaluations during stages and at peak, with hemodynamic validation.[7,13] Treadmill test is a good alternative, as abnormal findings in diastole persist after cessation of exercise.[3,4,14]

At our service, we use the treadmill with the Bruce protocol, and for patients with less mobility and for the elderly, modified Bruce protocol is used. Chart 1 shows the protocols, advantages and limitations, and Chart 2 shows the parameters of diastolic function and PASP.[3,4]

Keywords

Heart Failure; Echocardiography; Stress.

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The treadmill is placed next to the echocardiographic unit to allow the patient to move to the stretcher right after the exercise, and is performed as follows:

1. Diastolic function and PASP variables are taken.

2. Left ventricular (LV) images are acquired: longitudinal and cross-sectional parasternal views, apical 4 and 2 chamber view for the evaluation of segmental contractility.

3. Patients go to the treadmill with continuous 3-lead ECG monitoring and blood pressure evaluation every 3 minutes.

4. They are encouraged to reach the age-predicted maximum heart rate (HR) (220-age) or to observe when any symptoms are felt.

5. As soon as the exercise is finished, they quickly move to the

Chart 1 – Protocols, advantages and limitations.

Modality	Protocols	Advantages	Limitations
Bicycle (upright, semi-supine or supine position)	Default: initial load 25 W, 60 rpm, 25 W increments every 2 minutes	Physiological Best recommended as it allows an evaluation at each stage More time for peak exercise acquisition More sensitive to detect ischemia than treadmill (peak images) Hemodynamic validation with invasive studies	Little availability Patient moving during exercise may impair image acquisition Lower workload achieved compared to treadmill
Treadmill	Bruce: 10% initial inclination and 2% increments at each 3-minute stage, up to the 7th stage Modified Bruce protocol: 0% initial inclination, each stage lasting 3 minutes and inclination increments to 5, 10, 12 and 14% at the 5th stage	Physiological Fairly available Doctors and patients are more familiar Higher workloads Larger double product at the expense of higher HR It may be more specific for detecting ischemia than cycling	Technical difficulty acquiring images at peak exercise Possibility of normalization of abnormalities post-exercise Very short time to acquire images (60 to 90 seconds after exercise discontinuation) Wait for recovery HR to reach 100–110/min to avoid merging of mitral Doppler waves and mitral annulus tissue Doppler waves No hemodynamic validation with invasive measurements

W: Watts; rpm: revolutions per minute, HR = heart rate.

Chart 2 - Parameters acquired at TED at rest and during exercise (bicycle) or immediate post-exercise (treadmill).

Parameter	Acquisition	Advantages	Limitations
E	Apical 4-chamber view of LV Pulsed Doppler with 1 to 3 mm volume sample between the tips of the mitral valve cusps Optimize gain and filter Measure at peak early diastole velocity	Highly feasible and reproducible	Merger of E and A velocities with high HR Decreases with age Acquire when HR is between 100 and 110 beats/min
(lateral, middle) e'	Apical 4-chamber view of LV Mitral annulus tissue Doppler with 5 to 10 mm volume sample in the septal and lateral area Optimize gain and filter	Highly feasible and reproducible	Merger of e', a' velocities with high HR. Decreases with age. Limited accuracy in patients with segmental abnormality in the segment studied, mitral annulus calcification, prosthetic annulus, pericardial disease. Use septal e' preferably; use lateral e' if there is medial annulus calcification or septal segmental contraction abnormality. Different cutoff points depending on sample site.
E/e' ratio	Ratio of E and e' velocities	Highly feasible and reproducible Hemodynamic validation with bicycle exercise	Decreased accuracy in normal individuals, mitral annulus calcification, significant mitral and pericardial valve disease, segmental contraction abnormality in the segment studied. Results clash with hemodynamic validation in some studies. Different cutoff points depending on sample site.
PTRV	Apical 4-chamber view of LV or parasternal view of RV inflow tract Peak velocity obtained by continuous Doppler Optimize gain and filter to show complete flow curve	Indirect adjunct of LV filling pressure estimation	Increased exercise velocity may be due to pulmonary parenchymal disease or normal response to increased exercise flow in normal individuals. Complete signal of tricuspid regurgitation is not obtained in 1/3 of patients. Less reliable if there is severe tricuspid regurgitation.

LV: left ventricle; RV: right ventricle; HR: heart rate; beats/min: beats/minute; E: Mitral peak early filling velocity; e': Early diastolic filling velocity on septal and lateral mitral annulus tissue Doppler; E/e' ratio: Mitral E velocity divided by e' velocity; PTRV: Peak tricuspid regurgitation velocity.

stretcher in the left lateral decubitus position, with LV imaging taken as at rest, at 60 to 90 seconds, avoiding normalization of any segmental contraction abnormality.

6. Acquisition of tricuspid Doppler, as PASP tends to normalize rapidly after exercise ceases. Contrast infusion may improve Doppler tracing and endocardial borders, but it is not useful for tissue Doppler. Right atrial pressure is estimated to be between 5 and 10 mm Hg due to the difficulty in assessing inferior vena cava diameters during exercise.

7. Mitral and tissue mitral annulus Doppler when HR is 100–110 beats/min.

Interpretation of DSE

Patient's exercise capacity should be compared with age and gender nomograms, determining whether dyspnea is the main limitation for test discontinuation.

Chronotropic response of patients with HFpEF may present incompetence, i.e. they cannot reach 85% of the HR expected.[15]

We evaluated LV segmental contractility: images at rest and after immediate exertion side by side, aiming to rule out segmental contractility abnormalities as a cause of ischemia.

Interpretation of diastolic function:[3,4]

The test is normal if septal E/e' <10 at rest and exercise, and PTRV <2.8 cm/sec. at rest and exercise. (Figure 1)

The test is abnormal when septal e' <7 cm/sec. or lateral e' <10 cm/sec. at rest and, with exercise, septal E/e' is >15, mean E/e' >14, PTRV > 2.8 m/sec. (Figure 2).

Isolated PTRV increase should not be used as a diagnostic criterion for HFpEF, as it may be caused by normal hemodynamic response to exercise in the absence of PVFP elevation or pulmonary parenchymal disease.[12]

New perspectives

The incorporation of new techniques should include: longitudinal systolic function by global longitudinal strain, diastolic function by strain rate, LA strain and measurement of early LV suction with torsion parameters.

Conflict of interest

The authors declare that there is no conflict of interest regarding this manuscript.

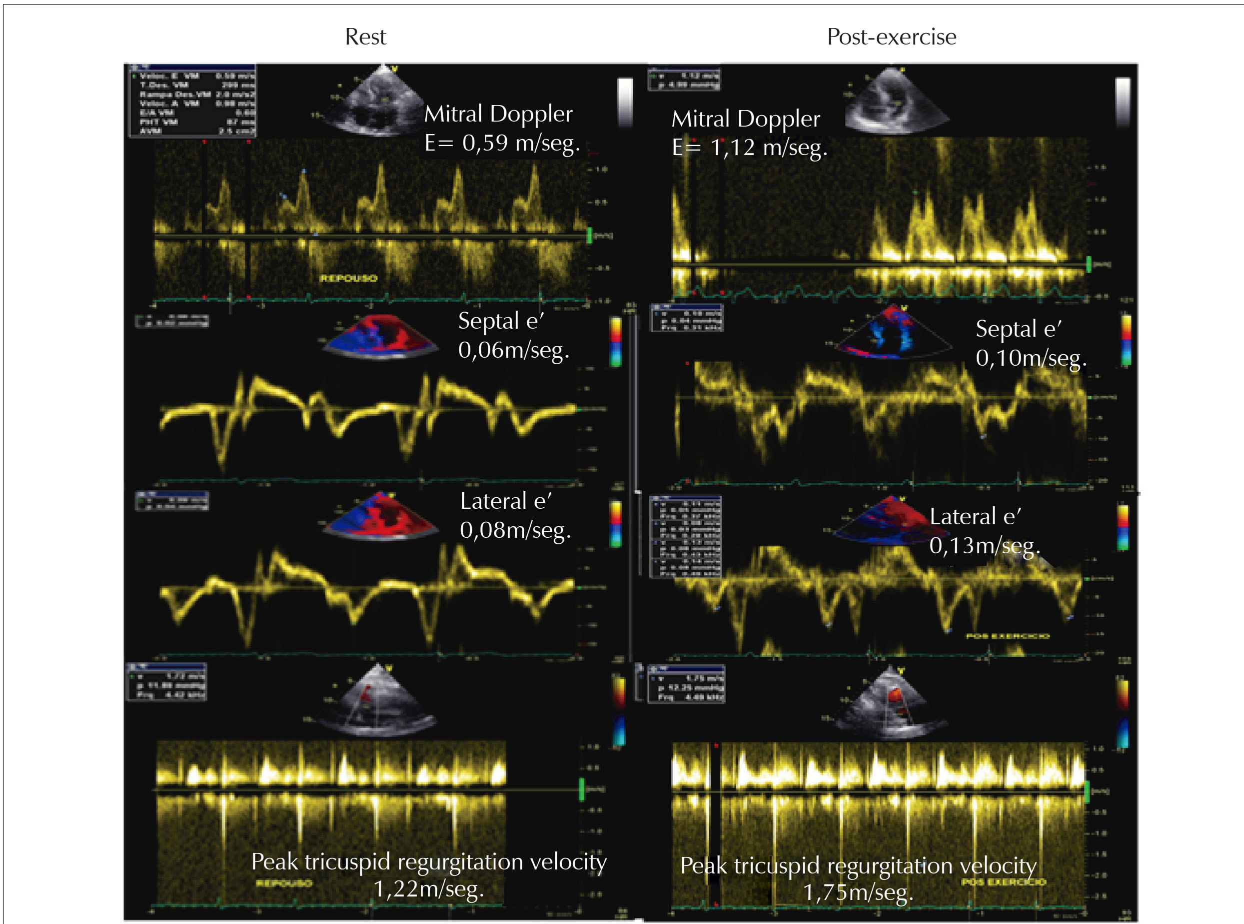

Figure 1 - *Female patient, 75 years old, hypertension and dyslipidemia, with dyspnea on exertion, submitted to modified Bruce protocol TED, with no LV segmental contractility abnormalities. Duration of 9 minutes, interrupted by fatigue, electrocardiogram with no abnormal findings. Submaximal HR was achieved with no abnormalities in segmental contraction after exercise. Medium E/e' at rest = 8.4 and PASP estimated at 16 mmHg. After exercise, medium E/e' = 9.7 and PASP estimated at 17 mmHg. Normal TED.*

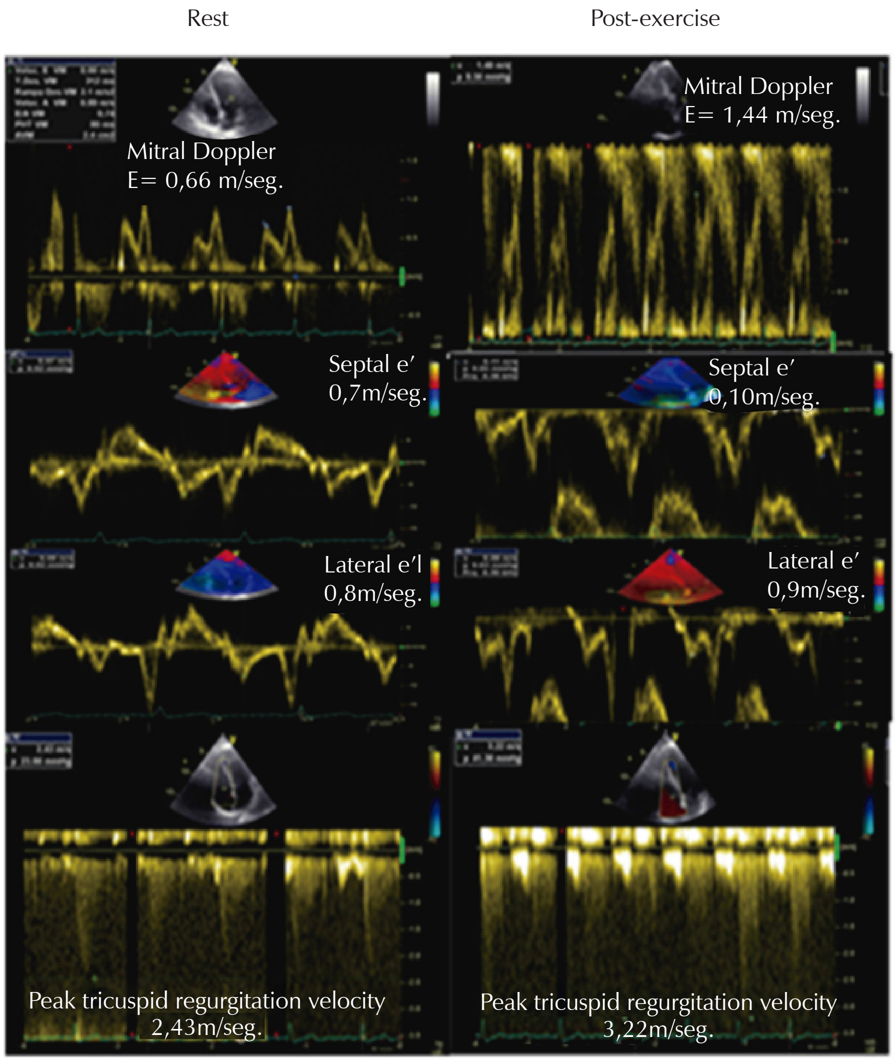

Figure 2 - *Female patient, 68 years old, arterial hypertension, diabetes and dyslipidemia, fatigue on medium exertion, submitted to Bruce protocol TED, with no abnormal findings in LV segmental contractility. The patient completed 7 minutes, presented moderate fatigue, reached 90% of the maximum expected HR. Electrocardiogram with no abnormal findings, no abnormalities in segmental contraction after exercise. Medium E/e' at rest = 8.8 and PASP estimated at 28 mmHg. After exercise, medium E/e' = 15 and PASP estimated at 46 mmHg. Abnormal TED.*

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