

Scisense PV Technical Note

Understanding Lusitropy: Passive Diastolic Properties and Active Myocardial Relaxation

Lusitropy describes the relaxation properties of the heart during the diastolic phase. Left Ventricle (LV) relaxation begins during late ejection and continues throughout an early rapid filling and ends fully relaxed by diastasis, before the atrial systole begins. Diastolic (lusitropic) properties can be described by both active relaxation and passive diastolic properties.

This active relaxation during diastole is a spatially non-uniform process, based on different rates and amounts of untwisting during periods of isovolumic ventricular relaxation (IVR). Twisting of the myocardial tissue leads to storage of potential energy that is freed in early ventricular diastole during untwisting. As the LV wall is composed of helically woven muscle layers and sheets, including extracellular matrix, all are assembled in interwoven layers such that fiber orientation is modified both transmurally and along the long axis of the ventricle (1). This LV geometric arrangement generates the spatially and temporally unique relaxation pattern accounting for unique, heart specific lusitropic patterns (1). Additionally, since LV and RV share the common septum, direct diastolic ventricular interaction is important to consider lusitropy when assessing the diastolic properties.

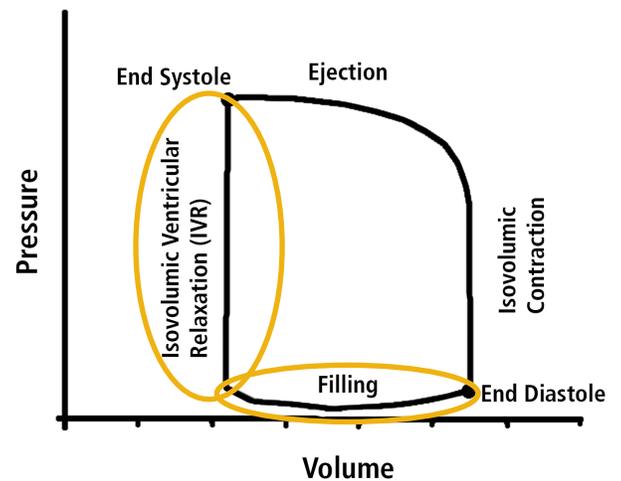


Fig. 1: Simplified sketch of LV PV loop. Diastolic phase includes isovolumic ventricular relaxation (IVR) and filling.

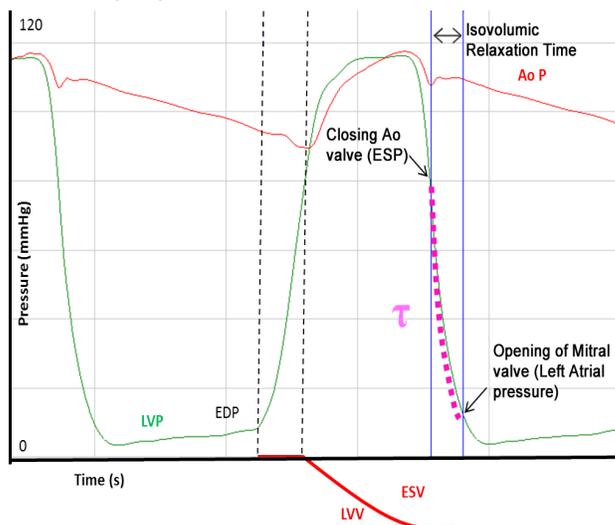


Fig. 2: The decay of LV pressure during the isovolumic ventricular relaxation (IVR) of diastole follows a roughly exponential time course. Active relaxation can be characterized by Tau, the segment of pressure contour between aortic valve closure and the mitral valve opening.

Understanding Lusitropy Cont.

ACTIVE RELAXATION PROPERTIES

- Indexed by Tau (isovolumic relaxation time, also known as time of pressure decay) IVR is from aortic valve closure to mitral valve opening
- dP/dt_{min} (is not as precise when compared to Tau, since dP/dt_{min} depends on the peak aortic pressure and timing of aortic valve closure) (2)
- Impacted by heart rate (HR)
- On cellular level, relaxation is energy consuming process requiring ATP as release of calcium from sarcomere requires SERCA (sarco-endoplasmic reticulum Ca-ATPase) for its re-uptake.

An increase in Tau indicates impairment of active properties of diastolic relaxation. Isovolumic relaxation and Tau are influenced by:

- Left atrial - left ventricle pressure gradient
- LV elastic recoil
- Chamber relaxation
- Mitral orifice area
- Heart rate
- Energy supply (Tau increases during MI and post-ischemia)
- Beta-stimulus (Tau decreases with β -adrenergic stimulation)

During many LV disease states (i.e. LV hypertrophy, LV ischemia, diabetic cardiomyopathy etc.) active relaxation is delayed.

When active relaxation is inadequate in early diastole, LV chamber relaxation might become incomplete at the end of diastole.

It is important to note that Tau has multiple methods of expression. Tau was originally used by Weiss to describe the IVR of LV (3). Raff and Glantz proposed an alternative method to express Tau, referred to as Tau Glantz (4). The latest IVR Tau logistic was proposed and described in 1995 by Dr. Suga in Japan (5).

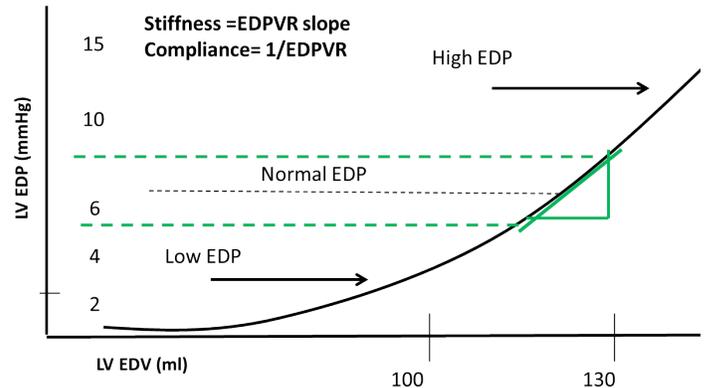


Fig. 3: Schematic drawing. EDPVR represents the relation between EDP and EDV, at the stage of the cardiac cycle that is marked by A-V (mitral) valve closure. The non-linear curve represents diastolic stiffness with the exponential fit $EDP=A \cdot \exp(k \cdot EDV)$, where k is diastolic stiffness constant. Since the EDPVR is nonlinear, the compliance varies with volume; compliance is greatest at low volume and smallest at high volumes.

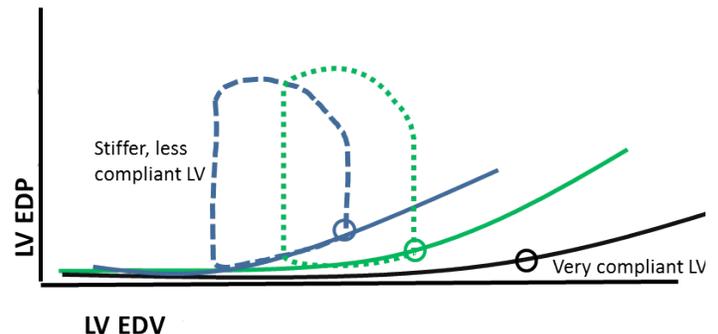


Fig. 4: Schematic drawing. EDPVR changes with lusitropic conditions. Examples of decreasing compliance detected by EDPVR leftward shift (stiffening of LV) include restrictive cardiomyopathy, infiltrative disease (amyloid), and hypertrophic cardiomyopathies.

Understanding Lusitropy Cont.

PASSIVE DIASTOLIC PROPERTIES

- Compliance (dV/dP , inverse of stiffness): LV compliance is determined by the substantial properties of the cardiac myocytes, cardiac fibroblasts, and other cardiac cells along with their cellular-molecular preparedness to contraction and relaxation.
- Stiffness (dP/dV , inverse of compliance)
- EDPVR: LV end-diastolic pressure-volume relationship provides an indication of LV compliance during the filling phase of cardiac cycle (Fig. 4 & Fig. 6). In late diastole passive properties of LV are more prominent as compared to active relaxation.
- Capacitance: Characterizes diastolic volume at given pressure. LV chamber geometry is important determinant of capacitance and its overall compliance (Fig 5).
- As myocardium is perfused mostly in diastole, stiffness of myocardium plays role in limiting coronary perfusion (7).

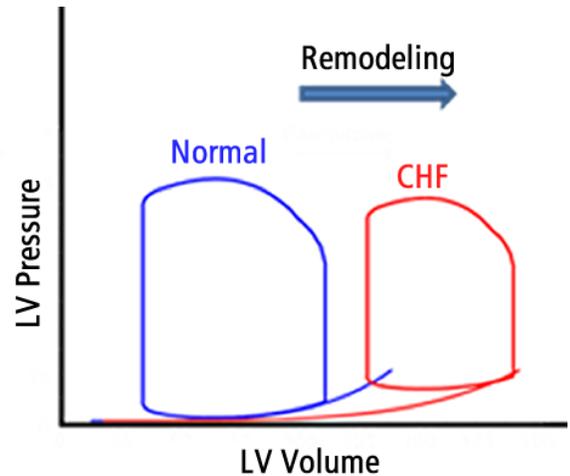


Fig. 5: Schematic drawing. Chronic heart failure (CHF) is seen in the late stages of post-myocardial infarct injury remodeling. Over time the remodeling mechanism persists beyond control and, in the non-injured region, cardiomyocytes hypertrophy and fibroblasts proliferate producing interstitial collagen. As the LV chamber volumes increase (EDV & ESV) the PV loop shifts to the right. However both SV and SW are diminished.

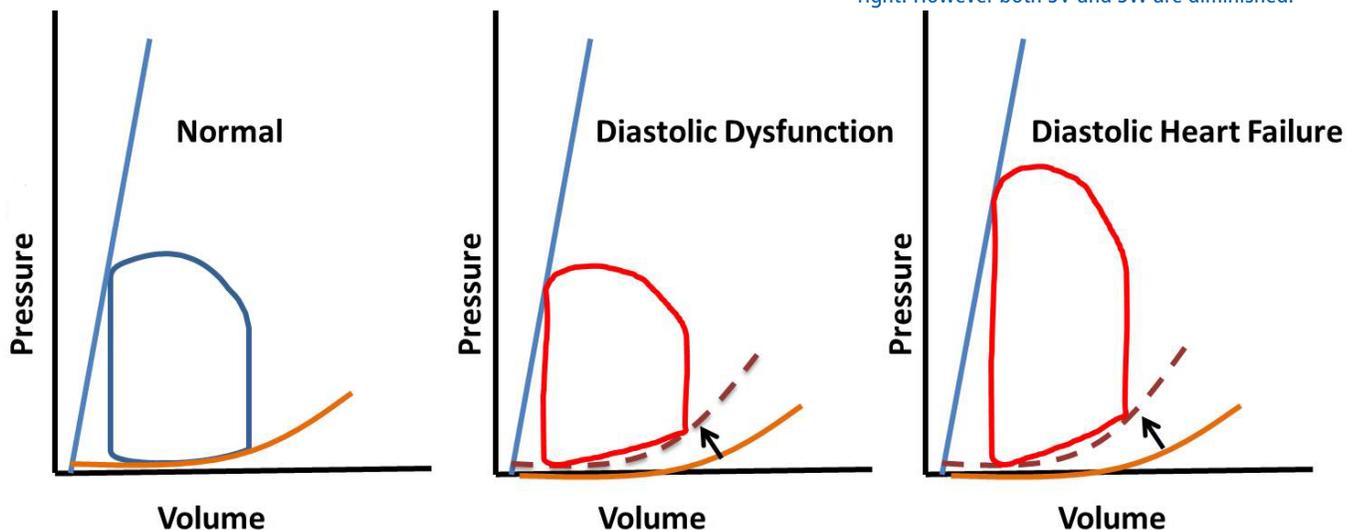


Fig. 6: Schematic drawing. Diastolic dysfunction is a syndrome characterized by impaired ventricular filling resulting from prolonged active LV myocardial relaxation and/or increased passive diastolic LV stiffness. Both indexes can help to determine diagnosis of diastolic dysfunction, and/or diastolic heart failure.

Understanding Lusitropy Cont.

Lusitropy can be further detected by non-invasive measurement of velocities of myocardial tissue using Tissue Doppler Imaging (TDI) echocardiography by Doppler E-wave deceleration time (DT) (Fig. 7). Many subjects with prolonged Tau interval (IVR) show a well delayed E-wave relaxation pattern on echocardiographic exam. However this relationship of Tau and E-wave does not always have good correlation since Tau requires a mathematical fit to the pressure contour (2).

Another method for assessing diastolic indices is speckle tracking echocardiography (STE), where myocardial speckles (small structures) are tracked to determine myocardial velocity and strain (6). Strain is the change in velocities length during a given time period, and it is possible to measure it by STE in the longitudinal, circumferential, transverse, and radial directions to assess regional diastolic function such as interstitial fibrosis in the region to identify myocardial viability.

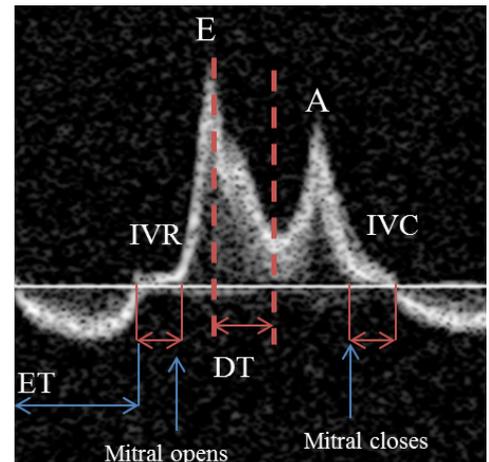


Fig. 7: E-wave deceleration time corresponds to diastolic relaxation properties. E-wave duration that is prolonged and lower in peak value than the A-wave, often represents underlying diastolic dysfunction. (IVC) Isovolumic contraction time, (DT) deceleration time, (IVR) Isovolumic relaxation time, (ET) ejection time.

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