

# **Non Invasive Evaluation of Ventricular Filling Pressures Using Tissue Doppler Imaging**

**Thesis**

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**Ahmed Shehata**

# Non Invasive Evaluation Of Ventricular Filling Pressures Using Tissue Doppler Imaging

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## Abstract:

**Background:** Left and right ventricular diastolic filling pressures are of clinical importance in both patient treatment and prognosis of cardiac and pulmonary diseases.

**Purpose:** To assess the ability of TDI - as a noninvasive method- to predict left ventricular filling pressures testing the validity of the current indices taking into consideration the controversies surrounding them and trying to drive new indices. In addition we assess its ability to predict right ventricular filling pressure especially in the presence of few data regarding this issue.

**Patients and methods:** The study population comprised two parallel groups of consecutive patients. The study groups were: Group A. In which conventional Doppler and TDI-derived echocardiographic variables were correlated with invasively measured LVEDP. Group B. In which conventional Doppler and TDI-derived echocardiographic variables were correlated with invasively measured RAP via a central venous catheterization.

**Results:** In group A. The median age of the patients was 55.5 years, 68% of them were males. Among all conventional and TDI indices measured, all conventional indices (E velocity, A velocity, E DT and E/A) together with both A' velocity and E'/A' showed the strongest correlation with LVEDP ( $r=0.59$ ,  $P < 0.001$ ) especially in patients with advanced diastolic dysfunction ( $r= 0.77$ ,  $p < 0.01$ ). Multiple regression analysis revealed that E'/A' is the best predictor of LVEDP having the greatest standardized coefficient B (0.4). Using linear regression analysis E'/A' showed the best model to predict the LVEDP ( $R=0.63$ ,  $p < 0.001$ ) especially in patients with advanced diastolic dysfunction ( $R=0.74$ ,  $p < 0.001$ ). Using ROC analysis,  $E-DT \leq 158$  msec can predict elevated LVEDP ( $> 15$  mm Hg) with 86.4% sensitivity and 84% specificity. In patient with advanced diastolic dysfunction  $A' \text{ velocity} \leq 10.5$  cm/sec and  $E'/A' \geq 1.29$  can predict elevated LVEDP with specificity of 100% and sensitivity of 93.8% and 70% respectively. In group B. The median age of the patients was 50 years, 76% of them were males. Regression analysis showed that E' velocity, IVRT, S duration and A velocity were the most important predictors of RAP. ROC analysis revealed that  $E/E' \geq 3$  is associated with 89% sensitivity and 100% specificity to detect  $RAP > 10$  mmHg and  $IVRT \leq 66.5$  msec was associated with 79% sensitivity and 100 % specificity to detect  $RAP > 10$  mm Hg.

**Conclusions:** Among conventional and tissue Doppler variables including the E/E' ratio, E'/A' ratio is the best index to estimate LVEDP especially in patients with advanced diastolic dysfunction (grade II and III). Both tricuspid E/E' ratio and IVRT are useful Doppler indices for non-invasive estimation of RAP.

**Key words:** Filling pressure, Tissue Doppler, Diastolic function

# *Contents*

<b>Item</b>	<b>Page</b>
<b>List of abbreviations</b>	<b>I</b>
<b>List of tables</b>	<b>IV</b>
<b>List of figures</b>	<b>VI</b>
<b>Introduction</b>	<b>1</b>
<b>Aims of the work</b>	<b>2</b>
<b>Review of literature</b>	<b>3</b>
▪ Chapter 1: Physiology of filling pressure	<b>3</b>
▪ Chapter 2: Determinants of filling pressure	<b>25</b>
▪ Chapter 3: Invasive estimation of left ventricular filling pressure	<b>47</b>
▪ Chapter 4: Invasive estimation of right ventricular filling pressure	<b>56</b>
▪ Chapter 5: Non invasive evaluation of ventricular filling pressure	<b>68</b>
<b>patients and methods</b>	<b>77</b>
<b>Results</b>	<b>85</b>
<b>Discussion</b>	<b>121</b>
<b>conclusion</b>	<b>134</b>
<b>Study limitations</b>	<b>135</b>
<b>Recommendations</b>	<b>136</b>
<b>Summary</b>	<b>137</b>
<b>References</b>	<b>139</b>
<b>Arabic summary</b>	<b>1-2</b>

## LIST OF ABBREVIATIONS

**2-D TDI:** Two dimensional tissue Doppler imaging  
**A:** Late diastolic wave  
**A':** Late annular motion  
**ACE:** Angiotensin-converting enzyme  
**ACS:** Acute coronary syndrome  
**ANOVA:** Analysis of variance  
**Ar:** Reverse pulmonary flow wave  
**AUC:** Area under the curve  
**BP:** Blood pressure  
**CAD:** Coronary artery disease  
**CHF:** Congestive heart failure  
**CI:** Confidence interval  
**CKD:** Chronic kidney disease  
**CVP:** Central venous pressure  
**D:** Pulmonary vein diastolic wave  
**DBP:** Diastolic blood pressure  
**DM:** Diabetes mellitus  
**dP/dt :** Rate of pressure change  
**dP/dt<sub>min</sub>:** Minimum rate of pressure change  
**DR:** diastolic flow reversal  
**E/A:** Ratio between early diastolic and late diastolic inflow velocity  
**E/E':** Ratio between early diastolic wave inflow velocity and early diastolic annular motion velocity  
**E/Pv:** Ratio between early diastolic wave amplitude of transmitral flow and its propagation velocity into the left ventricle  
**E:** early diastolic inflow velocity  
**E'/A':** Ratio between early diastolic wave amplitude of annulus movement and late diastolic wave amplitude of annulus movement  
**E':** early annular motion velocity  
**E'Acc<sub>rate</sub>:** early annular wave acceleration rate  
**E'Acc<sub>Time</sub>:** early annular wave acceleration time  
**E'Decel<sub>rate</sub>:** early annular wave deceleration rate  
**E'Decel<sub>Time</sub>:** early annular wave deceleration time  
**ECG:** Electrocardiogram  
**E-DT:** E wave deceleration time  
**EF:** Ejection fraction  
**HCM:** Hypertrophic cardiomyopathy  
**HVF:** hepatic vein flow  
**IPPV:** Intermittent positive pressure ventilation  
**IR:** Impaired relaxation  
**IVC:** inferior vena cava

**IVCT: Isovolumic contraction time**  
**IVR: Isovolumic relaxation**  
**IVRT: Isovolumic relaxation time**  
**KPa: Kilo Pascal (standard unit of pressure)**  
**LAP: Left atrial pressure**  
**LV: Left ventricle**  
**LVDP: Left ventricular diastolic pressure**  
**LVEDD: Left ventricular end diastolic dimensions**  
**LVEDP: Left ventricular end diastolic pressure**  
**LVEF: Left ventricular ejection fraction**  
**LVFP: left ventricular filling pressure**  
**MAP: Mean arterial pressure**  
**MFV: mitral flow velocity**  
**MR: Mitral regurge**  
**NS: Non-significant**  
**NYHA: New York Heart Association Functional Classification**  
**P wave: Propagation wave**  
 **$P_{\infty}$ : pressure asymptote**  
 **$P_a$  : Pulmonary alveolar pressure**  
**PA: Pulmonary artery**  
**PAC: pulmonary artery catheterization**  
 **$P_{AO}$ : Aortic pressure**  
**PAOP: pulmonary artery occlusion pressure**  
**PAP: Pulmonary artery pressure**  
**PAWP: pulmonary artery wedge pressure**  
**Pcap: Pulmonary capillary filtration pressure**  
**PCWP: Pulmonary capillary wedge pressure**  
**PEEP: Positive end expiratory pressure**  
**PFR: peak filling rate**  
 **$P_{IP}$  : Intrapleural pressure**  
 **$P_{LV}$ : Left ventricular pressure**  
**PN: Psedonormalization normal**  
 **$P_{PA}$ : Pulmonary artery pressure**  
 **$P_{RV}$ : Right ventricular pressure**  
**PTCA: percutaneous transluminal coronary angioplasty**  
**PV: Propagation velocity**  
 **$P_v$ : Pulmonary venous pressure**  
**PVF: pulmonary vein flow**  
**PW-TDI: Pulsed wave - tissue Doppler imaging**  
 **$Q_{AO}$ : Aortic flow**  
 **$Q_{PA}$ : Pulmonary artery flow**  
**RA: Right atrium**  
**RAP: Right atrial pressure**  
**RF: Restrictive filling**

**ROC: Receiver Operator Characteristics**  
**RV: Right ventricle**  
**RWMA: Regional wall motion abnormality**  
**S wave: Systolic wave**  
**SBP: Systolic blood pressure**  
**SF: Systolic fraction**  
**SGC: Swan Ganz catheter**  
**SR: systolic flow reversal**  
**Std: Standard**  
**Sv O<sub>2</sub>: Venous O<sub>2</sub> saturation**  
**SVC: Superior vena cava**  
**t: time**  
**T: time constant of isovolumic relaxation**  
**Tau: Time constant of left ventricular pressure decay**  
**TD: Tissue Doppler**  
**TDI: tissue Doppler imaging**  
**TDI: Tissue Doppler imaging**  
**TPFR: time to peak filling rate**  
**TR: Tricuspid regurge**  
**V<sub>0</sub>: Equilibrium volume**  
 **$\alpha$ : elastic parameter**  
 **$\beta$ : elastic parameter**  
 **$\gamma$ : viscoelastic parameter**  
 **$\epsilon$ : Lagrangian strain**  
 **$\dot{\epsilon}$ : strain rate**  
 **$\sigma$ : stress**

## List of tables

		<b>Page</b>
Table 1	Disorders involving abnormalities in diastolic left ventricular filling	<b>15</b>
Table 2	Lists of factors affecting the CVP	<b>59</b>
Table 3	Parameters for identification of patients with an elevated left ventricular filling pressure.	<b>72</b>
Table 4	Proposed formulas for the estimation of left ventricular filling pressure	<b>72</b>
Table 5	Intraclass correlation coefficient	<b>84</b>
Table 6	Baseline clinical and hemodynamic characteristics	<b>86</b>
Table 7	Echocardiography: 2- dimensional and color flow imaging	<b>86</b>
Table 8	Echocardiography: Conventional Doppler and TDI-derived measurements	<b>87</b>
Table 9	Linear correlation between LVEDP and Doppler indices	<b>88</b>
Table 10	Correlation between LVEDP and Doppler indices according to left ventricular systolic function	<b>91</b>
Table 11	Correlation between LVEDP and Doppler indexes in patients with RWMA	<b>92</b>
Table 12	Comparison between patients with and without elevated LVEDP	<b>93, 94</b>
Table 13	Comparison between patients with grade I versus grades II-III LV diastolic dysfunction	<b>97, 98</b>
Table 14	Relations between grades of LV diastolic dysfunction and Doppler indices by ANOVA	<b>100</b>
Table 15	Multiple regression analysis	<b>102</b>
Table 16	Linear regression analysis	<b>103</b>
Table 17	ROC analysis to predict elevated LVEDP (> 15 mmHg) in all patients	<b>105</b>



		<b>Page</b>
Table 18	ROC analysis to predict elevated LVEDP (> 15 mmHg) in patients with grades II and III LV diastolic dysfunction	<b>106</b>
Table 19	Baseline clinical and hemodynamic characteristics	<b>108</b>
Table 20	Echocardiography: Conventional Doppler and TDI-derived measurements	<b>109</b>
Table 21	Linear regression correlation between RAP and Doppler indices	<b>110</b>
Table 22	Comparison between patients with and without elevated RAP	<b>112, 113</b>
Table 23	Results of stepwise multiple regression analysis	<b>115</b>
Table 24	Coefficients of model 1, 2 and 6	<b>115</b>
Table 25	Confidence interval of model 2 and 6	<b>116</b>
Table 26	List of equation	<b>116</b>
Table 27	ROC analysis for prediction of elevated RAP	<b>119</b>

## List of Figures

		Page
Figure 1	Wiggers diagram	<b>8</b>
Figure 2	Plots of LV pressure versus length in normal and ischemic myocardial segments before and after rapid cardiac pacing in patient with single vessel coronary disease	<b>10</b>
Figure 3	LV time-activity curves and schematic representations of these curves in patient with CAD before and after coronary angioplasty. PFR improved from 1.1 to 2.3 EDV/sec after PTCA, and TPFR decreased from 186 to 166 msec, without change in baseline heart rate or ejection fraction.	<b>12</b>
Figure 4	Representations of ventricular pressure-volume relations in different forms of heart failure.	<b>13</b>
Figure 5	Several different factors affect the diastolic pressure during diastole, with different factors being important at different times	<b>25</b>
Figure 6	The rate, but not the extent, of left ventricular relaxation is slowed during reoxygenation after fifteen minutes of hypoxia.	<b>30</b>
Figure 7	Pressure-volume relations of the heart and pericardium, together and alone.	<b>38</b>
Figure 8	Hemodynamic response to the application and removal of 12 cm H <sub>2</sub> O positive end-expiratory pressure.	<b>40</b>
Figure 9 A & 9 B & 9 C	Two viscoelastic models used to describe muscle, the three-element model and the two-element (or Voigt) model (Panel A). Panel B shows the stress relaxation response of these two models, elicited by an imposed sudden, constant change in length (stress relaxation experiment). Panel C shows the corresponding results for creep experiments, when the change in length is measured in response to a sudden, constant change in externally imposed force	<b>43</b>
Figure 10	Typical waveform progression as the PAC floats through the cardiac chambers. Monitoring these waveforms tells the anesthesiologists where in the heart the catheter is as it advances	<b>50</b>
Figure 11	Physiologic lung zones. For pulmonary capillary wedge pressure to be reliable, the catheter tip must lie in zone 3.	<b>51</b>
Figure 12	Central venous pressure waveform from a ventilated patient (bottom) with time synchronized electrocardiograph trace (top).	<b>57</b>

		Page
Figure 13	Ventricular function and venous return curves	<b>60</b>
Figure 14	Ventricular diastolic pressure volume curve	<b>62</b>
Figure 15 A & 15B	<b>A.</b> A sample volume was placed 2-3 cm from inferior vena cava <b>B.</b> Pulsed wave Doppler recording of hepatic vein flow velocities in a normal subject. Systolic velocity (S) is usually greater than diastolic velocity (D), with no prominent reversal velocities (SR and DR). Both velocities are greater with inspiration than with expiration	<b>75</b>
Figure 16 A & 16 B & 16 C & 16 D	Hepatic vein Doppler recording from patients with restriction, pulmonary hypertension and severe tricuspid regurg A. restrictive cardiomyopathy. Systolic (S) forward flow velocity is smaller than diastolic (D) forward flow velocity. Inspiratory (Insp) diastolic flow reversal is larger than expiratory (Exp) diastolic flow reversal <b>B.</b> the recording of constriction is similar to that of restriction except that Exp diastolic flow reversal is larger than Insp diastolic reversal <b>C.</b> pulmonary hypertension. Diastolic flow reversal (arrows) does not change much with respiration <b>D.</b> Severe tricuspid regurg with late systolic flow reversal (arrow)	<b>75</b>
Figure 17	Example of Pulsed wave Doppler of the mitral flow	<b>79</b>
Figure 18	Example of PW-TDI of the lateral tricuspid annulus	<b>80</b>
Figure 19	Scatter plot showing the correlation between LVEDP and the following E velocity, A velocity, E-DT and E/A	<b>89</b>
Figure 20	Scatter plot showing the correlation between LVEDP both A' velocity and E'/A'	<b>90</b>
Figure 21	Correlation between E'/A' and LVEDP in patients with grade II-III diastolic dysfunction	<b>92</b>
Figure 22	E-DT in patients with and without elevated LVEDP	<b>95</b>
Figure 23	E'/A' in patients with and without elevated LVEDP	<b>95</b>
Figure 24	E/E' ratio in patients with grade I versus grades II-III LV diastolic dysfunction	<b>99</b>
Figure 25	E'/A' in patients with grade I versus grades II-III LV diastolic dysfunction	<b>99</b>
Figure 26	Relation between LVEDP and different grades of LV diastolic dysfunction by ANOVA	<b>101</b>
Figure 27	Relation between E/E' velocity and different grades of LV diastolic dysfunction by ANOVA	<b>101</b>

		Page
Figure 28	Relation between E'/A' velocity and different grades of diastolic dysfunction by ANOVA	102
Figure 29	Linear regression between E'/A' and LVEDP in all patients	103
Figure 30	Linear regression between E'/A' and LVEDP in patient with grade II and III diastolic dysfunction	104
Figure 31	Example of PW-TSDI of the lateral mitral annulus	104
Figure 32	ROC curve analysis of E-DT for prediction of LVEDP > 15 mmHg in all patients	105
Figure 33	ROC curve analysis of A' wave for the prediction of LVEDP >15 mmHg in patient with grade II and III diastolic dysfunction	106
Figure 34	LVEDP in patients with E/E' > 12 versus those with E/E' < 8	107
Figure 35	Linear regression between RAP and E/E'	111
Figure 36	Linear regression between RAP and IVRT	111
Figure 37	IVRT in patients with and without elevated RAP	114
Figure 38	E/E' in patients with and without elevated RAP	114
Figure 39	Bland-Altman plot of Doppler derived RAP pressure (using E/E') versus catheter derived RAP	117
Figure 40	Bland-Altman plot of Doppler derived RAP pressure (using E/E' & IVRT)	117
Figure 41	Example of PW-TDI of the lateral tricuspid annulus	118
Figure 42	ROC curve analysis for the prediction of RAP >10 mmHg for IVRT	120
Figure 43	ROC curve analysis for the prediction of RAP >10 mmHg for E/E'	120

## Introduction

Estimation of ventricular filling pressure is important in the assessment and management of cardiac patients especially under critical situations. Importantly, determination of ventricular filling pressure helps in the early initiation of appropriate therapy towards precise hemodynamic goals.

Central venous pressure (CVP) provides an estimate of the right atrial pressure and is used as a marker of cardiac preload.<sup>1,2</sup> Classically, CVP is measured invasively at the junction of superior vena cava and the right atrium.<sup>3</sup> Similarly, invasive methods are the golden standard to measure left ventricular filling pressure. This is performed using pulmonary artery catheter (in the wedge position) or via left ventricular catheterization.<sup>1,2,3</sup> It is obvious that these invasive procedures are expensive, need experienced hands, and are not without complications (e.g., pneumothorax, nerve injury, air-embolism, thromboembolism, infection).<sup>1,2,3</sup>

Various echocardiographic indices of transmitral and pulmonary vein flow have been combined to predict left atrial pressure noninvasively and, recently, tissue Doppler imaging (TDI) has showed promising role in this regard. TDI is a relatively new image modality that is based on quantification of myocardial velocities by consecutive phase shifts of the ultrasound signals reflected from the moving myocardium.<sup>4,5</sup> By combining transmitral E wave velocities with the velocity of motion of the lateral mitral annulus (Ea, which is a preload independent parameter), a reasonable estimate of left atrial pressure can be obtained. Naguel et al<sup>6</sup> found that an E/E' ratio of greater than 10 correlated well with the mean pulmonary capillary wedge pressure (PCWP) of greater than 15 mmHg. Omnen et al<sup>7</sup> confirmed this observation in another study. In this study, a ratio of (E/Ea) greater than 15 was identified in patients with elevated left ventricular end-diastolic pressure (LVEDP) greater than 12 mmHg. On the other hand an E/Ea ratio less than 8 accurately predicted normal LVEDP.

Although there are currently few data available, the previously mentioned early and well conducted studies are highly suggestive that the combination of TDI and mitral inflow velocities can be used for non invasive assessment of the LV filling pressure. On the other hand, and to the best of our knowledge, there is sparse data regarding the accuracy of TDI and tricuspid inflow velocities for the noninvasive estimation of right ventricular filling pressure.

## ***Aim of the work***

1-To assess the utility of several conventional Doppler and TDI parameters in the estimation of left ventricular filling pressures, trying to derive a new index that may be useful for the non-invasive estimation of left ventricular filling pressure.

2-To derive an echocardiographic index for estimating RAP using tricuspid annular velocity and inflow as assessed by conventional and tissue Doppler echocardiography.

## **Chapter 1**

### **Physiology of filling pressure**

Diastole, that portion of the cardiac cycle that begins with isovolumic relaxation and ends with mitral valve closure, results in ventricular filling and involves both active (energy dependent) and passive processes. The interactions between active processes (myocardial relaxation) that primarily influence early ventricular filling and passive processes, such as loading conditions, myocardial compliance, and valvular disease, are complex.<sup>8</sup>

Clinical methods to assess ventricular filling include cardiac catheterization, radionuclide angiography, and echocardiography. Any measurements of diastolic function must be made with an understanding of the determinants of ventricular filling and the limitations of the diagnostic test.

Many cardiac disorders are characterized by elevated pulmonary venous pressures in the face of normal systolic ventricular function, which suggests a primary abnormality of diastolic function. Abnormalities in diastolic function have been observed in coronary artery disease, congestive heart failure (with and without systolic dysfunction), hypertrophic cardiomyopathy, hypertension, and in healthy elderly subjects. Identification of these abnormalities may be useful clinically, particularly in patients with symptoms of heart failure and normal systolic function. Data are not available to determine the optimal therapy for such patients, although evidence suggests that calcium channel blockers, beta blockers, and agents that reverse myocardial hypertrophy may be useful.<sup>8</sup>

#### **Physiology of Diastole**

Diastole, a term derived from two Greek words meaning "to send apart," can be defined as the portion of the cardiac cycle that begins with isovolumic ventricular relaxation and ends with cessation of mitral inflow.

It is useful to define "normal" and "abnormal" diastolic function. In as much as normal heart function is concerned with the generation of adequate cardiac output at acceptable venous and arterial pressures, normal diastolic function may be defined as the level of ventricular filling needed to generate a cardiac output that is commensurate with