Non Invasive Evaluation of Ventricular Filling Pressures Using Tissue Doppler Imaging

Thesis

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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 ≤ 158 msec can predict elevated LVEDP (> 15 mm Hg) with 86.4% sensitivity and 84% specificity. In patient with advanced diastolic dysfunction A' velocity ≤ 10.5 cm/sec and E'/A' ≥ 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' ≥ 3 is associated with 89% sensitivity and 100% specificity to detect RAP > 10 mmHg and IVRT ≤ 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

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: Blod 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/dtmin: 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 $_{rate}$: early annular wave acceleration rate
E'Acc $_{Time}$: early annular wave acceleration time
E'Decel $_{rate}$: early annular wave deceleration rate
E'Decel $_{Time}$: 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_∞: pressure asymptote
Pa : 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
Pv: 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 O2: Venous O2 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_0 : Equilibrium volume
α: elastic parameter
β: elastic parameter
γ : viscoelastic parameter
ε: Lagrangian strain
έ: strain rate
σ: stress

List of tables

List of Figures

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 homodynamic goals.

Central venous pressure (CVP) provides an estimate of the right atrial pressure and is used as a marker of cardiac preload.[1,2] Classically, CVP is measured invasively at the junction of superior vena cava and the right atrium.[3] 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.[1,2,3] 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).[1,2,3]

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.[4,5] 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[6] 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[7]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.[8]

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.[8]

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