Original Article

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Tissue Doppler Imaging and Wall Acceleration During Weaning from Cardiopulmonary Bypass (CPB)

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Abstract

Background: Tissue Doppler Imaging (TDI) provides information of LV function. This study was designed to assess TDI and wall motion characteristics while weaning from CPB to determine the effect of volume loading on locoregional contractility. *Methods:* Fifty one cardiac surgical patients were evaluated. All patients requiring elective surgery and cross clamp period of less than 120 min. They underwent epicardial / transesophageal echocardiography while coming off CPB, during progressive loading of the heart. TDI and wall acceleration at mid papillary level (anteroseptal and posterior wall) were recorded. Patients with LV dysfunction and AR were excluded. *Results:* Mean ant wall 'e' and 'a' waves (early diastolic and late diastolic) values increased from 100% CPB to 50% on pump ('e': p value=0.03, 'a': p value=0.002) whereas for's' wave (systolic) value, significant increase was seen at 100% CPB to 75% on pump (p value=0.001). Mean post wall 'a' and 's' wave values increased from 100% CPB to 75% CPB whereas 'e' increased significantly after going off pump ('a': p value=0.001 , 's': p value =0.014 'e': p value =0.001). Mean wall acceleration of anteroseptal wall increased significantly from 100% CPB to 50% on pump (p value =0.001), whereas mean post wall acceleration did not increase significantly througout weaning from CPB but it was persistently higher than anteroseptal wall at all levels. There was no statistical difference for heart rate while coming off bypass. *Conclusion:* There is maximum increase in myocardial contractility (systolic and diastolic) due to preload augmentation between 75% to 50% of CPB while coming off bypass. There is minimal augmentation in contractility thereafter.

Keywords: Tissue Doppler Imaging; Cardio Pulmonary Bypass; Wall Acceleration.

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Introduction

The motion of a muscle is performed only by the Carnous fibers, and each Carnous fiber has a power of contracting itself. The force of the whole Muscle is but an aggregate of the contractions of each particular fiber.

—*William Croone in De rationemotusmusculorum*

(On the Reason of the Movement of the Muscles), 1664.

Tissue Doppler echocardiography (TDI) is a variation of conventional Doppler flow imaging. TDI is a useful method to detect locoregional contractility. This modality allows quantification of the Doppler shift within the range of myocardial tissue motion. Many efforts have been made to obtain an accurate estimation of the contractile performance of the ventricle. Unfortunately, most indices of ventricular function used in clinical practice (ejection fraction and stroke volume (SV)

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do not solely reflectthe contractile state of the ventricle [9]. An ideal index that could measure and translate these concepts and make them applicable to theintact heart should therefore be independent ofloading conditions (preload and after load), heartsize and mass, and sensitive to changes in inotropy [10]. Moreover, because goal directed therapy is associated with improvement ofoutcome [11], a load-independent index of ventricular contractility may permit a more accurate assessment and specifically tailored therapy. Several studies that haveassessed the prognostic significance of echocardiographic derived measurements, such as LVEF, LADs, LV mass systolic and diastolic time intervals and particularly those derived from Doppler studies of mitral inflow velocities such as deceleration time (DT). Studies that have used TDI, however, are limited [12]. This study can be used in predicting patients who may have difficulty while weaning from CPB.

Aim

The study was designed to assess TDI and wall acceleration characteristics while weaning from CPB and to determine the effect of volume loading on locoregional contractility.

Methods

Fifty one cardiac surgical patients were evaluated at Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bangalore form August 2016 to August 2017. All patientsrequiringelective surgery and cross clamp period of less than 120 min were evaluated by epicardial/transesophageal echocardiography while coming off CPB, during progressive loading of the heart. All patients were weaned off CPB with standard inotropic support that is 3 mcgof dopamine and dobutamine.TDI and wall acceleration at midpapillary level(anteroseptal and posterior wall) were recorded after 10 min of off cross clamp. Philips Envisor C HD machine was used for echocardiography. Probe S8 (8-12 MHz) and S4 (2-4MHz) were used for the study. Patients with LV dysfunction and AR were excluded.

In our study following measurements were made from the TDI recordings; peak systolic velocity (Sm), early (Em) andlate (Am) diastolic velocities at anterior and post wall at midpapillary level. Simultaneous measurement of wall motion velocity at anteroseptal and posterior wall was noted. All these measurements were taken while progressively coming off CPB. (at totally on pump at 100%, at 75%, at 50%, at 25% and completely off CPB.) Pulse rate, mean blood pressure and CVP was also noted down during all levels to determine the correlation.

Statistics

Data were tabulated in an Micorsoft Excel TM spread sheet and was imported into IBM SPSS 20™ (New York USA). A repeated measures ANOVA with a Greenhouse-Geisser correction was applied for repeated observetion. Bonferroni post-hoc test at various levels was done for pairwise comparision.

Results

The repeated measures ANOVA with a Greenhouse-Geisser correction showed that mean systolic, early diastolic and late diastolic values at anterior and posterior wall changed with a statistically significant difference between various CPB levels while coming off CPB (p value=0.0005). So the Post hoc tests using the Bonferroni correction was applied and pairwise comparison was done.

Mean ant wall ‘e’ wave (early diastolic) values increased by 6.8cm/sec (SE=3.028) from 100% CPB to 50% on pump (p value=0.030). Mean ’a’ (late diastolic) value increased by 11.9cm/sec (SE=3.571) from 100% CPB to 50% on pump (p value=0.002) whereas for ‘s’ wave (systolic) value, it increased by 10.2cm/sec (SE=2.995) from 100% CPB to 75% on pump (p value=0.001) [Table 1,2,3].

Table 1: Pairwise Comparisons (Ae)

Measure: Cms						
(I) CPB level	(J) CPB level	Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	1					
	2	-1.608	2.585	0.537	-6.799	3.583
	3	-6.765*	3.028	0.03	-12.846	-0.684
	4	-15.000*	2.862	0	-20.748	-9.252
	5	-15.431*	2.411	0	-20.275	-10.588

Table 2: Pairwise Comparision (AA)

Measure: Cms						
(I) CPB level	**(J) CPB level**	**Mean Difference (I-J)**	**Std. Error**	**Sig**	**95% Confidence Interval for Difference**	
					Lower Bound	**Upper Bound**
1	1					
	2	-5.098	2.774	0.072	-10.67	0.474
	3	-11.863*	3.571	0.002	-19.036	-4.689
	4	-17.412*	4.141	0	-25.728	-9.095
	5	-17.176*	3.545	0	-24.298	-10.055

Table 3: Pairwise Comparisons (AS)

Measure: Cms						
(I) CPB level	**(J) CPB level**	**Mean Difference (I-J)**	**Std. Error**	**Sig**	**95% Confidence Interval for Difference^b**	
					Lower Bound	**Upper Bound**
1	1					
	2	-10.196*	2.995	0.001	-16.212	-4.18
	3	-25.020*	3.588	0	-32.227	-17.813
	4	-35.235*	4.166	0	-43.602	-26.868
	5	-34.725*	3.871	0	-42.502	-26.949

Table 4: Pairwise Comparisons (PA)

Measure: Cms						
(I) CPB level	**(J) CPB level**	**Mean Difference (I-J)**	**Std. Error**	**Sig**	**95% Confidence Interval for Difference**	
					Lower Bound	**Upper Bound**
1	1					
	2	-9.961*	2.921	0.001	-15.828	-4.094
	3	-7.392	3.887	0.063	-15.199	0.415
	4	-13.392*	3.486	0	-20.394	-6.391
	5	-18.098*	3.672	0	-25.473	-10.723

Table 5: Pairwise Comparisons (PS)

Measure: Cms						
		Mean Difference (I-J)	**Std. Error**	**Sig**	**95% Confidence Interval for Difference^b**	
					Lower Bound	**Upper Bound**
1	1					
	2	-6.529*	2.575	0.014	-11.701	-1.358
	3	-15.333*	3.363	0	-22.089	-8.578
	4	-23.549*	4.3	0	-32.185	-14.913
	5	-29.549*	4.725	0	-39.039	-20.059

Table 6: Pairwise Comparisons (PE)

Measure: Cms						
		Mean Difference (I-J)	**Std. Error**	**Sig**	**95% Confidence Interval for Difference**	
					Lower Bound	**Upper Bound**
1	1					
	2	-2.51	1.912	0.195	-6.349	1.33
	3	-6.569	3.58	0.072	-13.758	0.621
	4	-5.549	3.857	0.156	-13.296	2.198
	5	-15.941*	4.041	0	-24.058	-7.824

Table 7: Pairwise Comparisons (WAA)

Measure: Cms						
		Mean Difference (I-J)	**Std. Error**	**Sig**	**95% Confidence Interval for Difference^b**	
					Lower Bound	**Upper Bound**
	1					
	2	-3.745*	1.863	0.05	-7.487	-0.003
1	3	-12.216*	2.557	0	-17.352	-7.079
	4	-13.176*	2.275	0	-17.746	-8.607
	5	-12.667*	2.53	0	-17.749	-7.585

Table 8:

CPB level	Dependent Variable
1	@100
2	@75
3	@50
4	@25
5	@0

Mean post wall 'a' wave value increased by 10.0cm/sec (SE=2.921) from 100% CPB to 75% CPB (P value=0.001). Mean 's' wave value increased by 6.6cm/sec (SE=2.575) from 100% CPB to 75% CPB (p value=0.014) whereas 'e' wave value increased by 16.0cm/sec (SE=4.041) after going off CPB. ('P value= 0.001) [Table 4,5,6].

Mean wall acceleration of anteroseptal wall increased by 3.8cm/sec (SE=1.863) from 100% CPB to 50% on pump (p value =0.001), mean post wall acceleration did not differ significantly throughout the weaning off of CPB but it was persistently higher than anteroseptal wall at all levels. [Table 7].

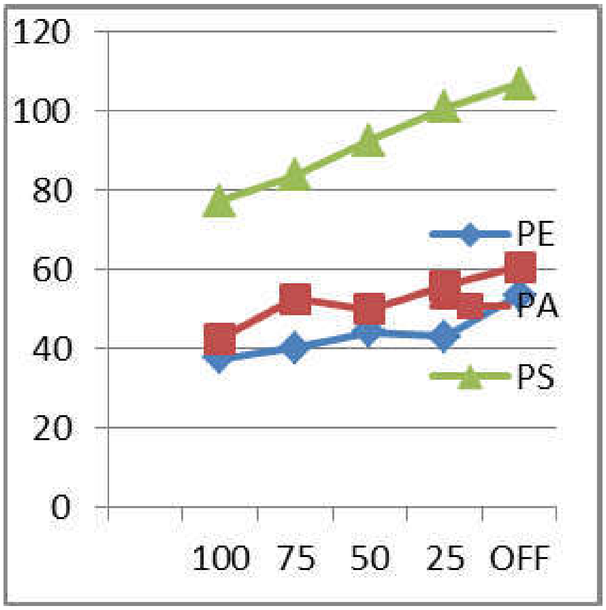

Fig. 1:

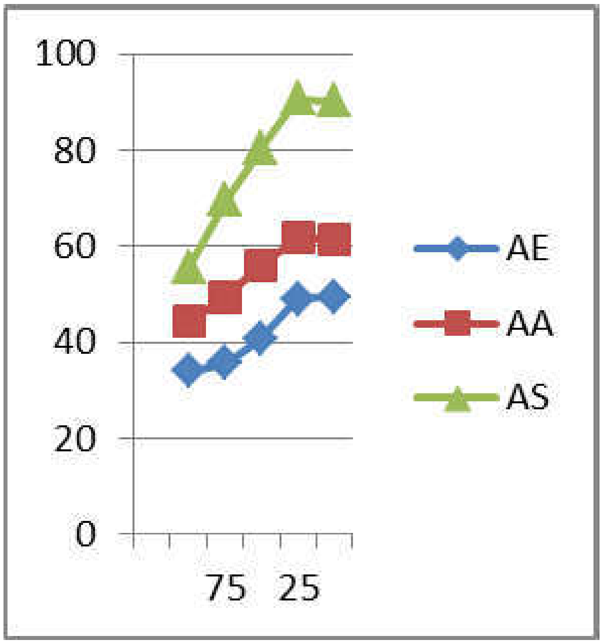

Fig. 2:

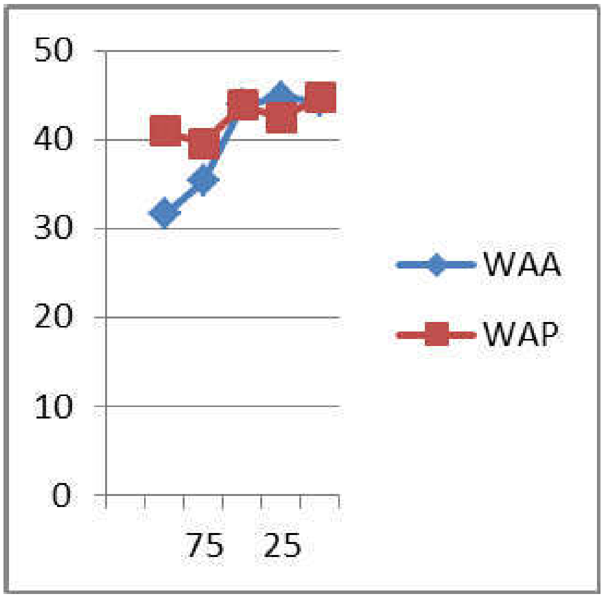

Fig. 3:

Discussion

Visual or semiautomated tracking of the endocardialborder provide estimates of cardiac volume, which areused to derive ejection fraction, a quantitative indicator of ventricular function. Ejection fraction reflects the sum contribution of severalregions and does not provide information on regional function. Regional function assessed visually is subjective andprone to error [1]. Quantification of regional myocardial activity (deformation) was feasible only in experimental studies by use ofmarkers attached directly to the myocardium, a technique notpracticable in the clinical realm [2]. Myocardial tagging withcardiac magnetic resonance (CMR) introduced the opportunityto noninvasively track regional myocardial mechanics. Modifications to the filter settings on pulsed Doppler toimage low-velocity, high-intensity myocardial signal ratherthan the high-velocity, low-intensity signal from blood flowallows similar assessment by ultrasound. This technique iscommonly referred to as tissue Doppler imaging (TDI) or Doppler myocardial imaging [3].

As early as 1973 Kostis et al. [4] first described pulsed wave Doppler technique for investigation of posterior wall velocities. Isaaz et al. found that low peak systolic velocity was associated with abnormal wall motion [5]. 1992 McDicken and Sutherland introduced a new technique for producing images of the velocity of tissue motion within the myocardium [6]. Based on the auto correlation signal processing color Doppler flow images were used to obtain myocardial tissue velocities [7]. 1994 Yamazaki et al. described this method for analysis of ventricular wall motion [8].

Technical Principles of TDI

Doppler signals from themyocardial wall exhibit low velocities (4–8 cm/s in healthy volunteers) with high amplitude. While in conventional Doppler techniques a high-pass filter prevents low-amplitude signal detection from the myocardium, in TDI this filteris bypassed and high frequency blood flow signals are eliminated by gain adjustment . (Fig.4)

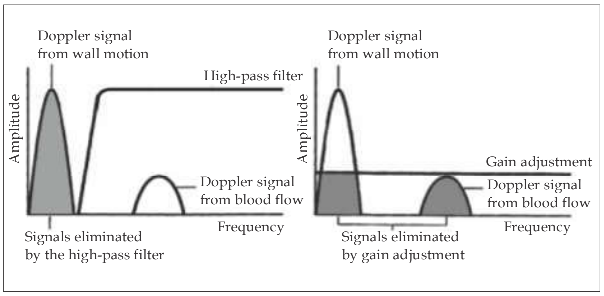

Fig. 4. Left: Principle of conventional Doppler. High amplitudemyocardial wall signals are eliminated by high pass filter. Right: Doppler signals from myocardial wall are extracted, blood flowsignals are eliminated. (Erbel R, Nesser HJ (eds). Atlas of tissue Doppler echocardiography.Steinkopff Verlag, Darmstadt, 1995; 9, fig. 3.1, 3.2).

To measure longitudinal myocardial velocities, the sample volume is placed in the ventricular myocardium immediately adjacent to the mitral annulus. The cardiac cycle is represented by 3 waveforms.

(1) Sa, systolic myocardial velocity above the baseline as the annulus descends toward the apex;

(2) Ea, early diastolic myocardial relaxation velocity below the baseline as the annulus ascends away from the apex; and

(3) Aa, myocardial velocity associated with atrial contraction.

The lower-case “a” for annulus or “m” for myocardial (Ea or Em) and the superscripted prime symbol (E') are used to differentiate tissue Doppler velocities from conventional mitral inflow. Pulsed-wave TDI has high temporal resolution but does not permit simultaneous analysis of multiple myocardial segments.

Clinical Applications of TDI:

- Assessment of LV Systolic Function
- Assessment of Diastolic Function

Novel Applications of TDI:

- Estimation of LV Filling Pressures
- Differentiation Between Constrictive and Restrictive Physiology
- Early Diagnosis of Genetic Disease
- Differentiation of Athlete’s Heart From HCM
- Assessment of Cardiac Dyssynchrony
- Assessment of Right Ventricular Function

TDI has established its applicability in various cardiac condition including CAD , cardiomyopathy, heart failure (systolic and diastolic). Right ventricular as well as atrial function can be very well assessed by TDI. Patients with low ejection fraction, conduction abnormality, and symptomatic heart failure despite optimal medical therapy experience significant benefits from cardiac resynchronization. Mechanical dyssynchrony as determined by TDImay be superior to electrocardiography in predicting responseto this therapy.

INTRAOP:

TOE/TTE diagnosis of myocardial ischaemia is based on visual assessment of regional LV wall motion. However, despite adequate training and experience there can be significant observer variation in the visual assessment of LV wall motion. Decisions based on the assessment of regional wall motion are often critical. For example,during cardiac surgery a new abnormality of wall motion in the revascularized territory can indicate graft failure and the need for revision of the anastomosis or another graft. Given the importance of such decisions, objective support of visual assessment would be useful. Tissue Doppler imaging (TDI) allows quantitative assessment of LV wall motion and may become such a method.

In our study, we found that for an increase of preload, there was a concomitant significant increase of Sm. This phenomenon can be simply justified by the length-dependent activation (Frank-Starling mechanism), which endows the ventricle with performance characteristics such that the heart ejects whatever volume it receives during diastole. Thus, an increase ofthe length of the myocardial fibers caused by an increase of EDV (Em and Am) will lead to an increase of SV, the velocity of shortening, and also an increase of Sm.

There is maximum increase in myocardial contractility (systolic and diastolic) due to preload augmentation between 75% to 50% of CPB while coming off bypass. There is minimal augmentation in contractility thereafter. Sm is alsoindependent of an increase of afterload which is also proved by our study as there was no significant improvement after 75% on pump to off pump.

Conclusion

To our knowledge, the present study is the first study investigating TDI parameters in relation to weaning off CPB .This is the baseline study, for subsequent clinical studies of abnormal hearts wherein TDI can be used for cases where there is difficulty in coming off bypass. Tissue Doppler imaging (TDI) has emerged as anadjunct tool in the diagnosis of regional wall motion abnormalities from CAD and many cardiac pathologies. Herein we propose its use in the cardiac operation theatre also.Dependence on clear and crisp visualization of both epi- and endocardium, error in measurements, calculations based on geometric assumptions that may not correspond to the true shape of the cardiac chamber, and examiner's experience level may make such evaluations prone to error. Additionally, these traditional methods cannot distinguish the effect of loading conditions on myocardial function. Tissue dopplerimaging (TDI) is a novel ultrasound tool and a valuable addition to Cardiac surgery's Armamentarium.

References

1. Hoffman R, Lethen H, Marwick T, Arnese M, Fioretti P, Pingitore A, Picano E, Buck T, Erber R, Flachskampf FA, Hanrath P. Analysis of interinstitutional observer agreement in interpretation of dobutamine stress echocardiograms. J Am CollCardiol. 1996;27:330–36.
2. Waldman LK, Fung YC, Covell JW. Transmural myocardial deformation in the canine left ventricle: normal in vivo three-dimensional finite strains. Circ Res. 1985;57:152–163.
3. McDicken WN, Sutherland GR, Moran CM, Gordon LN. Colour Doppler velocity imaging of the myocardium. Ultrasound Med Biol. 1992;18:651–654.
4. Kostis JB, Mavrogeorgis E, Slater A, Bellet S. Use of a range-gated, pulsedultrasonic doppler technique for continuous measurement of velocity of theposterior heart wall. Chest. 1972;62: 597–604.
5. Isaaz K, Thompson A, Ethevenot G, Cloez JL, Brembilla B, Pernot C. Dopplerechocardiographic measurement of low velocity motion of the left ventricularposterior wall. Am J Cardiol. 1989;64: 66–75.
6. McDicken WN, Sutherland GR, Moran CM, Gordon LN. Colour Dopplervelocity imaging of the myocardium. Ultrasound Med Biol. 1992;18:651–4.
7. Kasai C, Namekawa K, Koyano A, Omoto R. Real time two-dimensionalblood flow using an autocorrelation technique. IEEE Trans Ferro FreqContr. 1990;37:590–601.
8. Yamazaki N, Mine Y, Sano A. Analysis of ventricular wall motion using colorcoded tissue Doppler imaging system. Jpn J Appl Phys. 1994;33:3141–6.
9. Ama R, Segers P, Roosens C, Claessens T, Verdonck P, Poalaert J. The effects of load on systolic mitral annular velocity by tissue Doppler imaging. AnesthAnalg. 2004;99:332–8
10. Carabello BA. Evolution of the study of left ventricular function:everything old is new again. Circulation. 2002;105:2701–3.
11. Rivers E, Nguyen B, Havstad S, et al. Early goal-directed therapyin the treatment of severe sepsis and septic shock. N EnglJ Med. 2001;345:1368–77.
12. Mei Wang, Gabriel W. K. Yip, Angela Y. M. Wang, Yan Zhang, MDPik Yuk Ho et al. Peak Early Diastolic Mitral Annulus Velocity by Tissue Doppler Imaging AddsIndependent and Incremental Prognostic Value J Am CollCardiol. 2003;41:820–6.