



ASSESSMENT OF LEFT VENTRICULAR MECHANICS AND ENERGETICS IN VARIOUS TYPES OF LEFT BUNDLE BRANCH BLOCK USING ECHOCARDIOGRAPHY

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ABSTRACT

Background and Aim: Recent data suggested that one third of patients meeting conventional electrocardiographic (ECG) criteria for left bundle branch block (LBBB) may be misdiagnosed and new, stricter, ECG criteria for LBBB have been proposed (Strauss's criteria). Accordingly, we used two-dimensional speckle tracking echocardiography (2DSTE), to compare left ventricular (LV) mechanics in patients with LBBB according to conventional versus Strauss's ECG criteria for LBBB.

Methods: We studied 49 asymptomatic patients with incidental LBBB: 16 with conventional (mean age 69 years, 56% were men) and 33 with Strauss's criteria (mean age 66 years, 61% were men), LV ejection fraction (LVEF) $\geq 45\%$, and no significant obstructive coronary artery disease. Three-dimensional echocardiography was performed to measure LV end diastolic (LVEDV) and end systolic (LVESV) volumes, sphericity index (SpI), LV remodelling index (LVRI) and LVEF. 2DSTE was used to measure parameters of LV dyssynchrony: septal to posterior wall time to peak radial strain (SW-PW delay), longitudinal strain delay index (L-SDI), longitudinal strain rate dispersion index (L-SRDI) and LV mechanical dispersion (LVMD). In addition, we also measured LV cardiac work indices: global work efficiency (GWE), global work index (GWI), global constructive work (GCW), and global wasted work (GWW).

Results: Among dyssynchrony parameters; L-SDI was significantly higher in patients with Strauss's criteria than in conventional one ($37 \pm 17\%$ vs $25 \pm 10\%$, respectively, $p = 0.007$). Moreover, GWW tended to be higher in patients with Strauss's criteria than in conventional one ($325 \pm 132\%$ vs $267 \pm 124\%$ respectively, $p = 0.079$). In all patients, LVESV index was positively correlated with GWW ($r = 0.51$, $p = 0.001$). This correlation may further support the use of LVESV index change as an echocardiographic predictor to assess LV remodelling after cardiac resynchronization therapy (CRT).

Conclusion: Patients in whom LBBB was diagnosed according to stricter (Strauss's) ECG criteria showed significantly higher intraventricular dyssynchrony and tendency for higher LV wasted work than patients with LBBB according to conventional ECG criteria. Further studies are needed to assess if the same occurs in patients with LVEF $< 35\%$ considered for CRT and further stratification of patients according to ECG pattern may improve the selection of patients who would benefit from CRT.

Keywords: Left bundle branch block, Strauss, Dys-synchrony, CRT, Echocardiography, Left ventricular mechanics.

INTRODUCTION

Left bundle branch block (LBBB) is an interruption in the normal electrical sequence of activation of

the heart muscle. This is reflected by an abnormal pattern seen on the surface electrocardiogram (ECG). This block may occur along the left bundle branch arising from the His-

Purkinje system and may result in various ECG patterns.⁽¹⁾ LBBB may be rarely seen in asymptomatic young individuals with a structurally normal heart,^(2,3) but it is often associated with underlying heart disease especially when it is of recent onset. These adverse effects of LBBB may be due to the altered sequence of the electrical left ventricular (LV) activation which is then followed by abnormal sequence of LV mechanical contraction even in the absence of structural heart disease. Investigation of the electrical activation pattern in LBBB patients is limited by the presence of comorbidities and the lack of knowledge regarding the duration and extent of the lesion (or lesions).

Identifying complete LBBB on the ECG is not fully standardized and straightforward. Conventional criteria for LBBB, which are widely used clinically and were applied in large trials. In 2009 American Heart Association, American College of Cardiology Foundation and Heart Rhythm Society suggested updates to the conventional diagnostic criteria of LBBB which additionally included broad notched or slurred R wave in leads I, aVL, V5 and V6.⁽⁴⁾ Strauss *et al.* in 2011 presented new criteria for diagnosing LBBB in which they emphasized that mid-QRS notching is the key feature of LBBB because these notches denote endocardium and lateral LV wall breakthrough of the depolarization wave front.⁽⁵⁾

The abnormal and dyssynchronous contraction in patients with LBBB increases the LV work as while some

segments contract, they will stretch the not yet contracting segments, thus resulting in energy loss, waste of myocardial work and ineffective LV ejection.⁽⁶⁾ LV work could be quantified by using a recently developed and validated noninvasive tool namely regional LV pressure – strain loop area.⁽⁷⁾ Along with segmental and global values for myocardial work, a set of additional indices are also calculated:⁽⁷⁾

- 1- Constructive work: it is the positive work performed by a segment during shortening in systole in addition to the negative work during lengthening in isovolumetric relaxation (IVR).
- 2- Wasted work: it is the negative work performed by a segment during lengthening in systole in addition to the positive work performed during shortening in IVR.
- 3- Myocardial work efficiency: is estimated by dividing the constructive work by the sum of constructive and wasted work (0-100%).

Measurement of regional myocardial electrical–mechanical events using velocity data acquired with

tissue Doppler imaging (TDI) showed limitation in assessment of dys-synchrony in patient going to have CRT. To overcome these limitations, new parameters were proposed like, the strain delay index (SDI), strain rate dispersion index (SRDI) and mechanical dispersion (MD).

METHODS

Study population:

We studied 49 asymptomatic subjects with incidental LBBB: 16 with conventional (mean age 69 years, 56% were men) and 33 with Strauss's criteria (mean age 66 years, 61% were men). Thorough clinical history and examination of all subjects were done. Standard 12 leads ECG was done and the subjects classified according to the following criteria as in the following table (1):^(4, 5)

Table (1): ECG criteria for diagnosis complete LBBB in adults.

Criteria	AHA/ACC/HRS* (conventional)	D. Strauss
QRS duration (m/f, ms)	≥120/≥120	≥140/≥130
QRS notching or slurring	Broad notched/slurred R wave in leads I, aVL, V5, and V6	Mid-QRS notching/slurring in ≥2 of leads V1, V2, V5, V6, I, and aVL
QS or rS in leads V1 and V2	-	✓
Delayed intrinsicoid deflection (>60 ms)	Present in leads V5 and V6 absent in leads V1, V2, and V3	-
Usually discordant ST and T wave	✓	-
Q waves in leads I, V5, and V6	Absent	May present in patients with concomitant anterior and/or apical infarct

Then 2D and 3D echocardiographic assessment of all subjects were done with measurement of:

- a. EDV, ESV, LVEF.
- b. Global longitudinal strain (GLS).
- c. Longitudinal strain delay index (L-SDI).
- d. Longitudinal strain rate dispersion index (L-SRDI).
- e. Left ventricular mechanical dispersion (LVMD).
- f. Septal to posterior wall time to peak radial strain.
- g. LV mass, LV sphericity index and LV remodelling index.
- h. GWE, GWI, GCW, GWW and WWR.

Standard transthoracic echocardiography was performed using a Vivid E9 and Vivid E 95 ultrasound system, (GE Vingmed Ultrasound AS, Horten, Norway) equipped with a M5S 3.5-mHz transducer.

STATISTICAL ANALYSIS⁽⁸⁾

Data were expressed as mean ± standard deviation for continuous variables and as percentages for categorical variables. Between-group comparisons were performed using Student's t-tests or χ^2 test, as appropriate. Statistical significance was defined as $p < 0.05$. Statistical analysis was performed using SPSS Version 20.0

RESULTS:

In our study; we studied different echo derived intra-ventricular dys-synchrony indices including classic velocity-time delay indices as well as speckle tracking echo (STE) derived indices and correlating them with

myocardial segmental work in subjects with different electrocardiographic morphological patterns of LBBB with no underlying significant cardiac disease except for the electrical abnormality. In other words, "pure LBBB". We recruited prospectively 49 consecutive subjects with LBBB and applied manual criteria for differentiation of Strauss apart from conventional patterns. Strauss criteria were applied in about 67.3% versus 32.7% diagnosed with conventional pattern. The mean age of the all subjects in both groups was 66.82 ± 14.1 in our study.

Among dyssynchrony parameters; L-SDI was significantly higher in patients with Strauss's criteria than in conventional one (37±17% vs 25±10%, respectively, p = 0.007) as seen in table (2).

Moreover, GWW tended to be higher in patients with Strauss's criteria than in conventional one (325±132% vs 267±124% respectively, p = 0.079, table 3).

Left ventricular remodelling index (LVRI) and sphericity index (sp. Index) were found to be positively and negatively -respectively- correlated with GWE, GWI and GCW with statistical significance only in conventional group and not in Strauss group. While GWW was not found to be correlated significantly neither with LVRI nor Sp. Index in both groups (table 4). This means that in patients with conventional criteria of LBBB have better constructive based global work indices when they have increased LV mass in excess to LV dilatation, probably as an adaptive mechanism, with less spherical -globular- left ventricular morphology

Table (2): Comparison between the two studied groups according to L-SDI.

	Total (n = 49)	QRS morphology		Test of Sig.	P
		Group I (n = 16)	Group II (n = 33)		
L-SDI					
Min. – Max.	10.29 – 81.11	10.29 – 61.88	14.26 – 81.11		
Mean ± SD.	33.09 ± 17.25	24.99 ± 14.26	37.02 ± 17.39	U = 138.0*	0.007*
Median	27.79	19.48	33.47		

Table (3): Comparison between the two studied groups according to GWW

	Total (n = 49)	QRS morphology		T	P
		Group I (n = 16)	Group II (n = 33)		
GWW					
Min. – Max.	81.0 – 751.0	81.0 – 480.0	132.0 – 751.0		
Mean ± SD.	306.6 ± 133.6	267.9 ± 128.3	325.3 ± 134.0	1.424	0.079
Median	300.0	254.0	316.0		

Table (4): Correlation between global work indices and LV remodelling parameters

	GWE					
	Total sample (n = 49)		Group I (n = 16)		Group II (n = 33)	
	R	P	R	P	R	P
LV RI	0.324	0.031*	0.542	0.015*	0.205	0.523
Sp. Index	-0.313	0.028*	-0.617	0.011*	-0.148	0.412
	GWI					
	Total sample (n = 49)		Group I (n = 16)		Group II (n = 33)	
	R	P	R	P	r	P
LV RI	0.305	0.033*	0.654	0.004*	0.070	0.651
Sp. Index	-0.305	0.033*	-0.690	0.003*	-0.085	0.638
	GCW					
	Total sample (n = 49)		Group I (n = 16)		Group II (n = 33)	
	R	P	r	P	r	P
LV RI	0.345	0.064	0.626	0.009*	0.142	0.723
Sp. Index	-0.241	0.096	-0.704	0.002*	0.005	0.976
	GWW					
	Total sample (n = 49)		Group I (n = 16)		Group II (n = 33)	
	R	P	r	P	r	P
LV RI	-0.131	0.254	-0.081	0.657	-0.196	0.401
Sp. Index	0.203	0.161	0.051	0.852	0.175	0.329

DISCUSSION:

Direct assessment of intra-ventricular LV dys-synchrony in LBBB subjects using traditional qualitative parameters namely abnormal segmental motions like septal flash and apical rocking movements in addition to quantitative parameters like septal to posterior wall delay assessed by time to peak radial strain were assessed in both groups. Septal flash assessed visually and confirmed by TDI was found nearly in 80% of the whole cohort while apical rocking movement was found in about 85%. Septal to posterior wall time to peak radial strain was found to be less than 130 milli-seconds (commonly used as a cut off for intra-ventricular dys-synchrony in literature) in all subjects. ⁽⁹⁾ Comparing both groups shows no significant difference between them regarding these parameters

except for the apical rocking movement was significantly present more in Strauss group than conventional one. These contradictory results of qualitative and quantitative parameters signifying intra-ventricular dys-synchrony urged the need for newer dys-synchrony indices to confirm the coupling of electrical and mechanical dys-synchrony.

In our study we used mechanical dispersion, longitudinal strain delay index and longitudinal strain rate dispersion index as a novel quantitative dys-synchrony index. Prolonged mechanical dispersion reflects increased temporal heterogeneity of myocardial contraction and has been reported to be useful to stratify arrhythmic risk among patients with different cardiac condition. ⁽¹⁰⁻¹²⁾ The mean MD in our study compared to the mean reference

value for the same age group as our study population as proposed by Hugo and his colleagues was significantly higher in the whole cohort and consistently higher in both groups as well. The mean in our study was 52.41 ± 14.80 msec while the reference physiological value is 41 ± 10 msec.⁽¹³⁾ Despite our study did not prove significant difference between conventional and Strauss groups regarding mechanical dispersion; MD was statistically significant negatively correlated with GWE in conventional group and even with higher significance negatively correlated with GWE in Strauss group. It has had also very significant positive correlation with GWW in both groups. These results render MD - as a dys-synchrony parameter- a good predictor of wasted energy in different subsets of LBBB patients and this of importance considering the results of several studies showing a good correlation between CRT responders and post implantation reduction of MD.⁽¹⁴⁾

Assessment of longitudinal strain delay index (L-SDI) allowed not only to confirm the dys-synchrony pattern seen in LBBB with delayed post systolic shortening of the lateral segments, but also to quantify the potential wasted energy exerted by these segments contracting while other segments are relaxing. It is worthy to be noted that in our study we measured the strain delay index in both delayed post systolic shortening lateral segments as well as early pre-systolic peaking septal segments as they are both lose their effective contribution to ejection phase. Other studies mainly using L-SDI in patients with cardiomyopathy before CRT implantation; used to mark L-SDI in dys-synchronous segments with positive peaks (stretch) more than their negative peaks (contraction) as zero denoting that they are scarred with no significant contractile reserve.⁽¹⁵⁾ We adopted the same concept. However; considering our study group population with isolated LBBB and preserved systolic function we did not encounter such a case. In our study; L-SDI was statistically significant higher in Strauss group than conventional one. Also, it had consistent significant negative correlations with GWE, GWI, GCW and significant positive correlation with GWW rendering L-SDI -as a dys-synchrony parameter- a perfect proof of evidence that Strauss LBBB pattern had lower constructive work and higher wasted work mainly due to its higher dys-synchrony pattern more than conventional LBBB pattern.

The concept of the SRDI is based on the following hypothesis. If LV contraction was synchronized, global LV systolic function will theoretically be equal to the average of segmental systolic function. Thus, the average of the segmental peak systolic SR, one part of the SRDI, represents the global LV systolic function when contraction is synchronized, whereas global peak systolic SR, the other part of the index, represents that in the presence of dys-synchrony. Therefore, the SRDI, which is the difference between the averaged 18 segments systolic SR and the global LV systolic SR is a direct measure of the magnitude of global dys-synchrony.⁽¹⁶⁾ However; in our study, L-SRDI failed to show significant difference between both groups and failed to show significant correlation with global work analysis parameters.

Direct comparison of both groups regarding global work parameters showed no significant difference regarding GWE, GWI and GCW. This sounded logic considering pre-selection of the whole cohort with preserved ejection fraction and more importantly healthy subjects with no overt, sub clinical heart failure nor associated obstructive coronary artery disease. However; Strauss group tended to have more wasted work than conventional one (P value = 0.079). Indexing the negative work to the positive work to get global wasted work ratio (GWWR) discriminated both groups significantly. Strauss group had significant more GWWR than conventional one (P value = 0.036).

CONCLUSION:

In our study; we found that regardless baseline patient demographic and clinical characteristic; electrocardiographic Strauss LBBB pattern with basic echo study shows large LV volumes, spherical configuration and apical rocking movement denotes more dys-synchrony related wasted myocardial work and energy which can be good target for therapy by means of resynchronization therapy with predictable good response. Conventional LBBB pattern may need further dys-synchrony assessment namely higher mechanical dispersion which correlates significantly with GWE.

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