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Original Research Article

Evaluation of left ventricular longitudinal function and synchrony after dual chamber pacemaker implantation

Kristina Baronaitė-Dūdonienė [a,*], *Jolanta Vaškelytė* [b], *Aras Puodžiukynas* [a], *Vytautas Zabiela* [a], *Tomas Kazakevičius* [a], *Gintarė Šakalytė* [a]

[a] *Department of Cardiology, Medical Academy, Lithuanian University of Health Sciences, Kaunas, Lithuania*
[b] *Institute of Cardiology, Medical Academy, Lithuanian University of Health Sciences, Kaunas, Lithuania*

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ABSTRACT

Background and objective: To evaluate left ventricular (LV) longitudinal function and dyssynchrony mechanisms after dual chamber pacemaker implantation.
Materials and methods: The speckle tracking imaging technique was used for quantification of global longitudinal function of the left ventricle and for dyssynchrony evaluation before pacemaker implantation and after 3-month follow-up. The study group consisted of 98 patients with conventional indications for dual chamber pacemaker implantation.
Results: Speckle tracking echocardiographic methods and image postprocessing revealed impairment of global longitudinal strain and significant LV dyssynchrony derived from 12 basal and mid-septum segments usually untraceable with conventional echocardiographic methods. Despite good physical performance and ejection fraction, global longitudinal strain significantly decreased in all patients from -15.08 ± 0.46 to -13.56 ± 0.5 ($P < 0.05$) as well as mitral annulus movement decreased from 11.57 ± 2.41 to 8.46 ± 1.74 cm/s ($P < 0.001$) and from 12.55 ± 2.75 to 10.78 ± 2.82 mm ($P < 0.001$). It was expected that patients with dual chamber pacemaker will develop inter- and intraventricular dyssynchrony, but our study showed that pacing lead position did not prevent from LV dysynchronisation and only changed the mechanism.
Conclusions: Global longitudinal strain and LV dyssynchrony assessment enables us to detect early signs of LV dysfunction. Mechanisms of dyssynchrony development will be useful for pacemaker programing choices in order to prevent further dyssynchronisation.

* *Corresponding author at*: Department of Cardiology, Medical Academy, Lithuanian University of Health Sciences, Eivenių 2, 50161 Kaunas, Lithuania.
E-mail address: kristinabar@gmail.com (K. Baronaitė-Dūdonienė).
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1. Introduction

Dual-chamber (DDD/R) pacing was developed two decades ago, to restore atrioventricular (AV) synchronization in patients with AV block and represented a significant technological advance at that time. Multiple studies have demonstrated the hemodynamic superiority of AV sequential pacing over single ventricular pacing (VVI/R). A properly timed atrial systole improves stroke volume through the Frank-Starling mechanism. Higher left ventricular (LV) end-diastolic pressures and volumes – higher systolic and mean blood pressures and lower right atrial and pulmonary capillary wedge pressures have been reported with AV synchronous pacing [1]. A variety of invasive and noninvasive hemodynamic studies have documented a 10% to 53% improvement in cardiac output with AV sequential pacing compared with VVI pacing [1,2].

These generally consistent improvements in cardiac output led to conclusions that AV sequential pacing would reduce the risk of heart failure, reduce mortality, and improve quality of life [1]. Also DDD/R was described as the physiological pacing mode.

Despite this, research data in patients with pacemakers for sick sinus node dysfunction or AV block provide increasing evidence showing that dyssynchronization of ventricular electrical activation and contraction, induced by right ventricular pacing (RV) worsens long-term cardiac morbidity and mortality.

The risk of heart failure is increased even in hearts with initially normal pump function and in case of part-time ventricular pacing. These epidemiologic data fit with knowledge from decades of pathophysiological research, indicating that RV pacing creates abnormal contraction, reduced pump function, causes hypertrophy and ultrastructural abnormalities [2].

The aim of our study was to evaluate mechanism of LV remodeling and dyssynchronisation by using 2D echocardiography with speckle tracking imaging.

2. Materials and methods

The study group consisted of 98 subjects with a mean age of 70.51 ± 13.46 years. All of them were admitted to the Clinic of Cardiology, Hospital of Lithuanian University of Health Sciences, due to conventional indications for dual chamber pacemaker implantation: sick sinus node syndrome or second to third degree AV block.

Before procedure and at 3-month follow-up, physical examination, electrocardiography, 6-minute walk test (6-MWT), and echocardiography were performed and evaluated by using conventional and speckle tracking imaging (STI) techniques. Only patients with certain (at least 90%) right ventricular pacing percentage were selected for further analysis. Patients with lower ventricular pacing could misrepresent LV remodeling mechanisms.

The patients were divided into two groups: 46 patients (45.1%) with apical ventricular lead position (first group) and 52 patients (54.9%) with mid-septum ventricular lead position (second group). Lead positioning was not predefined before pacemaker implantation – a decision was made by a surgeon regarding anatomical situation.

2.1. Conventional echocardiography

Echocardiographic technique and calculations of morphometric parameters were performed in accordance with the recommendations of The American Society of Echocardiography 2005 [3–5]. The biplane Simpson's rule was used for calculation of global LV ejection fraction (EF). To evaluate longitudinal left ventricle function we used measurement of mitral annular longitudinal movement assessed by M-mode and by tissue Doppler imaging (TDI).

2.2. Interventricular and intraventricular dyssynchrony

Interventricular dyssynchrony represents the discordance between the times of right ventricular (RV) and LV contraction. Pulsed wave (PW) or continuous wave (CW) Doppler images of aortic and pulmonary flow velocities were used to measure the interventricular mechanical delay (IVMD), which includes recording of LV outflow tract (apical 5-chamber view) and RV outflow tract (parasternal short-axis view of the great vessels) and calculating the difference in time between ECG-derived Q wave onset and the onset of LV outflow and the time between the onset of Q and the onset of RV outflow. These time intervals respectively reflect LV and RV pre-ejection period (PEP). IVMD values of >40 ms and values of LV PEP of > 140 ms are considered as pathological [6,7].

Intraventricular dyssynchrony was evaluated by using two methods. First one was M-mode-derived septal-to-posterior wall motion delay (SPWMD), i.e., the difference in timing of septal and posterior wall contraction [7]. The SPWMD is the difference between the time from the onset of ECG-derived Q wave to the initial peak posterior displacement of the septum, and the time from the onset of QRS to the peak systolic displacement of posterior wall. SPWMD >130 ms was considered pathological. Second method was based on STI techniques which measure the standard deviation of the averaged time-to-peak-strain (TP-SD) of 12 LV basal and mid-segments obtained from the three standard apical views: a TP-SD of >60 ms was considered as pathological [8].

2.3. Automated single speckle tracking imaging

For 2D speckle tracking echocardiography analysis we used Vivid 7 (GE Vingmed Ultrasound AS, Horten, Norway) equipment. Tissue harmonic images were scanned at long-axis apical three standard apical views with the M3S probe. The mean frame rate was 60 frames per second (range 40–80). Data were stored on the hard disc of the echocardiographic machine, and transferred to a workstation (EchoPAC PC, GE Vingmed) for offline analysis. For further analysis LV was divided into 6 long axis segments in each view.

The system calculates mean global strain and strain rate (SR) values for all predefined LV segments.

2.4. Statistical analysis

Statistical analysis was performed with software SPPS version 20.0 (IBM SPSS, Inc., Chicago, IL, USA).

A P value less than or equal to 0.05 was considered as statistically significant.