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Comparative study of lead placement in the right ventricular apex vs. right ventricular outflow tract: effects on left ventricular systolic dysfunction, dilatation, and myocardial performance – a single-center experience

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Stimulace hrotu PK
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Stimulace výtokového traktu PK

SOUHRN

Cíl: Cílem této studie bylo analyzovat rozdíl mezi stimulací hrotu pravé komory (PK) a výtokového traktu PK na jedné straně a incidencí systolické dysfunkce levé komory (LK), její dilatací a indexem výkonnosti myokardu levé komory (left ventricular myocardial performance index, LVMPI) na straně druhé po dvou letech od implantace.
Metody: Naše studie byla retrospektivní observační. Účastníky studie byli pacienti s jednodutinovým trvalým kardiostimulátorem PK (permanent pacemaker, PPM) po dvou letech od implantace přístroje ve všeobecné nemocnici Soetomo Surabaya General Hospital. Shromažďovali jsme vstupní charakteristiky pacientů, elektrokardiografický záznam a zátěž kardiostimulátorem PPM. Následně jsme vypočítávali hodnoty LVMPI, rozměry srdečních komor, hodnotili systolickou funkci LK, ejekční frakci levé komory (EF LK) 3D technikou, a celkovou longitudinální deformaci (global longitudinal strain, GLS) 3D technikou.
Výsledky: Byl nalezen statisticky významný pokles ve všech parametrech systolické funkce LK ve skupině po implantaci PPM do hrotu PK (p = 0,003), včetně přístroje Biplane (p = 0,034), EF LK po implantaci dvoudutinového přístroje do hrotu (apical 2-chamber, A2C) (p = 0,029), EF LK po implantaci čtyřdutinového přístroje do hrotu (apical 4-chamber, A4C) (p = 0,038), v hodnotách GLS 3D (p = 0,031) i EF LK 3D (p = 0,003). Bylo zjištěno i statisticky významné zvýšení hodnoty dilatace LK ve skupině s hrotem v PK, pouze však u mužů, i když hodnota byla stále ještě v rámci normálních hodnot (průměr LK na konci diastoly [LV end-diastolic diameter, LVEDd], p = 0,01). Konečně bylo zaznamenáno statisticky významné snížení LVMPI ve skupině v hrotu PK (p = 0,001).
Závěry: Existuje statisticky významný rozdíl mezi implantací PPM do hrotu PK oproti stimulaci výtokového traktu PK v incidenci systolické dysfunkce levé komory (LK), dilatace LK a v indexu výkonnosti myokardu levé komory (left ventricular myocardial performance index, LVMPI) po 2 letech od implantace.

Keywords:
Pacemaker complications
Right ventricular pacing
RV apex pacing
RVOT pacing
Single-chamber pacing

ABSTRACT

Aim: This study aims to analyze the difference of right ventricular (RV) apex and right ventricular outflow tract (RVOT) pacing with the incidence of left ventricular (LV) systolic dysfunction, LV dilatation, and left ventricular myocardial performance index (LVMPI) after 2 years of implantation.
Methods: This is an analytic observational study with a retrospective cohort design. The study subjects were patients using single-chamber RV pacing permanent pacemaker (PPM) after 2 years of implantation at Soetomo Surabaya General Hospital. We collected baseline characteristic data, electrocardiogram, and PPM burden. Subsequently, LVMPI, cardiac chamber dimensions, LV systolic function, left ventricular ejection fraction (LVEF) 3D, and global longitudinal strain (GLS) 3D were obtained.

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Results: There was a significant decrease in all LV systolic function parameters in the post-PPM RV apical group (p = 0.003), including BIPLANE (p = 0.034), LVEF apical 2-chamber (A2C) (p = 0.029), LVEF apical 4-chamber (A4C) (p = 0.038), GLS 3D (p = 0.031), and LVEF 3D (p = 0.003). There was also significant increase in LV dilatation parameters in the RV apex group for men group only, although still within normal limits (LV end-diastolic diameter [LVEDd], p = 0.01). Finally, there was a significant decrease in the LVMPI in RV apex group (p = 0.001).

Conclusions: There is a significant difference between the implantation of PPM with RV apex pacing compared to RVOT pacing with the incidence of left ventricular (LV) systolic dysfunction, LV dilatation, and left ventricular myocardial performance index (LVMPI) after 2 years of implantation.

Introduction

The development of implantable pacemaker technology since the mid-20th century has been crucial for life-saving patients with bradyarrhythmia. In the last few decades, the indications for and number of permanent pacemaker implantations have increased rapidly along with the development of new technology.[1,2] Over time, various modifications to lead implantation methods have been developed to optimize function and reduce side effects. To date, the placement of leads in the right ventricular (RV) apex has become standard practice owing to the ease of access and lower cost compared with dual chamber pacemakers.[1] Although RV pacing is generally effective and well tolerated, subsequent studies have raised concerns about the safety of RV apex pacing.[1,3,4] This phenomenon occurs because a single lead stimulation in the RV, particularly at the RV apex, creates an LBBB activation pattern.[5] Approximately 10–20% of patients with pacemakers, after 2–4 years of implantation experience a significant decrease in left ventricular function (ejection fraction ≤45%), resulting in cardiomyopathy called pacemaker-induced cardiomyopathy (PiCMP).[6]

Several studies have been conducted to determine the prevention of long-term adverse effects of RV apex pacing.[4,7,8] Various recent studies have found that the narrowest QRS is achieved by RVOT, particularly in the septum.[6,9] Pacing in this position is considered more physiological because it involves the Purkinje network earlier than apical pacing, thereby reducing the electrical and mechanical dyssynchrony associated with RV apex pacing.[10] This effect was explained by better preservation of left ventricular ejection fraction (LVEF) during follow-up with less left ventricular dilatation and mitral regurgitation compared with apical pacing.[11–13] However, RVOT pacing itself has also been associated with reduced ventricular dyssynchrony.[13,14] The latest ESC guidelines on cardiac pacing and cardiac resynchronization therapy also do not state any recommendations regarding the selection of one RV pacing location over another.[15] Data on the prevalence of PiCMP and clinical outcomes after long-term RV pacing are also limited because not all patients require continuous RV pacing, comorbid diseases that often occur in patients with pacemakers, which can cause adverse LV remodelling, and periodic monitoring of LV function that is not routinely performed after pacemaker implantation.[16] Related research in Indonesia remains minimal, with small sample sizes and short evaluation periods. Aiming to decrease reliance on RV apex pacing and to discover improved ventricular pacing techniques.

Material and methods

Patient population and selection

This retrospective cohort study was conducted at Dr. Soetomo Hospital, Surabaya. All patients provided written informed consent to participate in the study, and the study protocol was approved by the ethics committee of Dr. Soetomo Hospital, Surabaya (protocol number: 0477/KEPK/IX/2022). This study included 56 patients (37 patients using RV apex leads and 19 patients using RVOT leads) using a single chamber, RV pacing, and permanent pacemaker (PPM) after 2 years of implantation. In addition, patients who met the requirements in this study were patients with LVEF pre-PPM implantation >45%; burden pacing ≥80% for 2 years; did not have structural heart disease pre-PPM implantation (significant heart valve disease, uncorrected congenital heart defects, right heart failure / right heart remodelling, left heart failure / left heart remodelling); and did not have severe comorbid diseases with cardiac complications (such as, systemic lupus erythematosus with cardiac complications, diabetes mellitus with cardiac complications, and haemorrhagic / ischemic stroke with cardiac complications). Some exclusions in this study are pregnant or lactating mothers and patients with mental disabilities. Data collection of respondent characteristics using a form (age, gender, comorbid diseases, treatment history).

Electrocardiogram recording and permanent pacemaker interrogation

A 12-lead electrocardiogram (ECG) recording was performed using a 3/6/12 channel Aspel Mr. Silver ECG machine. Eligible patients underwent a 12-lead ECG recording, and the performance of the PPM was assessed based on the recording results to determine its effectiveness. In addition to ECG recording, patients were subjected to PPM interrogation according to the type of generator and lead used. Three devices were used in this hospital, namely Medtronic, St. Jude, and Biotronic. This interrogation was performed to determine the PPM burden in patients. Patients who had a burden of ≥80% for 2 years were included in this study.

Transthoracic echocardiography

Transthoracic echocardiography was performed using a Philips Epiq CVx device. Patients who met the criteria underwent transthoracic echocardiography to assess LV systolic function after PPM implantation, either by Simpson's method (BIPLANE) or by other parameters, such as LVEF Apical 2-Chamber (A2C), LVEF Apical 4-Chamber (A4C), GLS 3D, and LVEF 3D. Furthermore, LV dimension assessment was performed using the left ventricular end--diastolic diameter (LVEDd) method and volume, namely end-diastolic volume (EDV) and end-systolic volume (ESV). To assess the systolic and diastolic ability of the myocardium, the Left Ventricular Myocardial Performance Index (LVMPI) was measured by measuring the mitral valve and left ventricular outflow tract flow.

Follow-up cohort

Patients who use single-camber PPM on RV for 2 years will be contacted for inclusion criteria screening and asked for their willingness to be included in this study. Patients who agree to participate will be asked to attend a check--up at the integrated heart service center polyclinic of Dr. Soetomo Hospital, Surabaya. Participants will be provided an explanation of the procedures and objectives of this study. Each respondent who agreed to participate in the study will sign a letter of informed consent. Respondents who agree will have their basic characteristics data collected using a form (age, gender, comorbid diseases, treatment history), ECG recording, PPM interrogation, and transthoracic echocardiography.

Statistics

Baseline demographic, clinical, and echocardiographic data were analysed using descriptive statistics and presented as means, standard deviations, counts, and percentages. Multivariate analysis was performed to assess the role of confounding variables, which was only performed for variables with a p value <0.25 in the bivariate analysis. Inferential analysis included normality testing using the Kolmogorov–Smirnov test. Comparisons between groups were performed using the paired t-test and independent t-test if the data were normally distributed or the Wilcoxon test or Mann–Whitney test if the data were not normally distributed. Differences in categorical data were assessed using the chi-square test if the sample was eligible or the Fischer exact test if the sample was not eligible. A probability value of p <0.05 was considered statistically significant. All statistical analyses were performed using SPSS version 24.0 (SPSS Inc., Chicago, IL).

Results

Demographic data

In the results of the basic characteristics of the study sample, 56 patients were included, with 37 using RV apex leads and 19 using RVOT leads. The average age of the participants was 68.16 years (28–85 years). There were no significant differences in the distribution of age between the two groups (**Table 1**). Almost two-thirds of all partici-

Table 1 – Characteristics of the participants

Characteristics	Category	Lead		
		RVOT	Apex	*p*-value
Age, median (min–max)		70 (35–85)	71 (28–83)	0.842
Sex, n (%)	Males Females	11 (57.9) 8 (42.1)	10 (27) 27 (73.0)	0.049*
HTN, n (%)	No Yes	7 (36.8) 12 (63.2)	17 (45.9) 20 (54.1)	0.714
DM, n (%)	No Yes	15 (78.9) 4 (21.1)	26 (70.3) 11 (29.7)	0.707
Smoking, n (%)	No Yes	12 (63.2) 7 (36.8)	30 (81.1) 7 (18.9)	0.192
Consumption of alcohol, n (%)	No	19 (100)	37 (100)	–
CAD family history, n (%)	No	19 (100)	37 (100)	–
LVEF Simpson's baseline, mean (SD)		65.16 (4.84)	66.89 (4.88)	0.212
PPM indication, n (%)	TAVB HDAVB AF Sinus Arrest	13 (68.4) 2 (10.5) 2 (10.5) 2 (10.5)	27 (73.0) 5 (13.5) 5 (13.5) 0 (0)	0.250
Beta-blocker, n (%)	No Yes	18 (94.7) 1 (5.3)	34 (91.9) 3 (8.1)	1.000
Spironolactone, n (%)	No Yes	16 (84.2) 3 (15.8)	35 (94.6) 2 (5.4)	0.324
ACEI/ARB, n (%)	No Yes	11 (57.9) 8 (42.1)	28 (75.7) 9 (24.3)	0.223

ACEI – angiotensin-converting enzyme inhibitors; AF – atrial fibrillation; ARB – angiotensin II receptor blockers; CAD – coronary artery disease; DM – diabetes mellitus; HDAVB – high-degree atrioventricular block; HTN – hypertension; LVEF – left ventricular ejection fraction; PPM – permanent pacemaker; SD – standard deviation; TAVB – total atrioventricular node block.

pants consisted of female patients (62.5%), with the rest being male. There was a high prevalence of hypertension, which was 32 patients (57.1%), which was evenly distributed in both groups. There was also a fairly high prevalence of diabetes mellitus (26.8%) and smoking habits (25%). None of the groups consumed alcohol or had a family history of coronary heart disease. The average baseline LVEF using Simpson's BIPLANE method was 65.16% ± 4.84% in the RVOT lead group and 66.89% ± 4.88% in the apical lead group.

Complete heart block or total atrioventricular node block (TAVB) was the most common indication for PPM implantation in both groups, with a total of 40 patients (71.4%), followed by high-degree atrioventricular node block (HDAVB) in 7 patients (12.5%), atrial fibrillation (AF) in 7 patients (12.5%), and sinus arrest in 2 patients (3.6%). There were no significant differences between the two RV pacing lead groups in terms of comorbid diseases (hypertension, diabetes mellitus) or medication consumption (ACE-inhibitors, ARBs, and MRA).

Comparison between the RV apex pacing vs. RVOT with the occurrence of left ventricular systolic dysfunction

The ejection fraction parameter used in the comparison of pre- and post-PPM implantation was Simpson's method (BIPLANE). In the RV apex lead group, there was a significant decrease in LVEF BIPLANE in the pre- and post-PPM implantation conditions (p <0.001), with an average in the pre-PPM group of 66.89% ± 4.88% and in the post-PPM group of 59.48% ± 9.75%. In the RVOT lead group, there was no significant decrease in LVEF BIPLANE in the pre- and post-PPM conditions, with a mean in the pre-PMM group of 65.15% ± 4.84% and a mean post-PMM of 64.76% ± 5.53 (p value = 0.793). When comparing the two lead groups in terms of pre- and post-PPM implantation conditions, no difference was observed between the RVOT and RV apex groups pre-implantation, as they had not yet been exposed to PPM (p = 0.212) (**Fig. 1**). After PPM implantation, a significant difference was observed between the two groups (p = 0.034). The average difference (delta) in the decrease in LVEF BIPLANE between the two lead groups also showed a significant difference of 7.01% ± 2.20% (p = 0.003).

In addition to LVEF BIPLANE, LV systolic function is described by several other parameters, including LVEF A2C, LVEF A4C, GLS 3D, and LVEF 3D. All LV systolic function

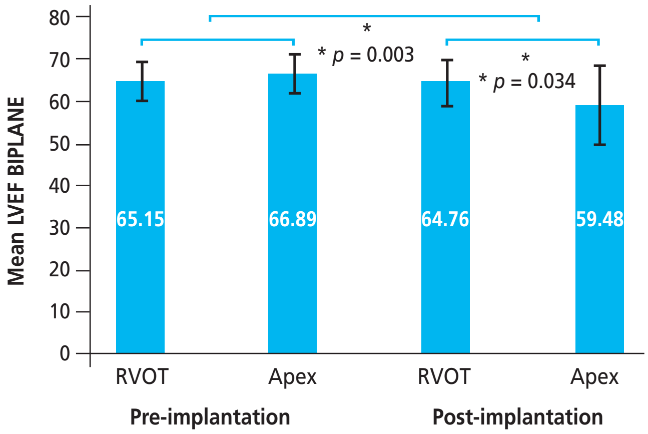

Fig. 1 – Comparison of the LVEF BIPLANE between the lead groups before and after PPM implantation. There is a significant difference in the average BIPLANE LVEF values between the RVOT group (64.76% ± 5.53%) and the Apex group (59.48% ± 9.75%) following implantation. The average difference in BIPLANE LVEF between the two groups was also significant (7.01% ± 2.20%). In the RVOT group, LVEF values remained relatively stable before and after implantation, indicating that the functioning of the RVOT lead is closely aligned with normal heart function.

parameters showed significant differences between the RV apex lead group and the RVOT lead group (**Table 2**), namely LVEF A2C (p = 0.029), LVEF A4C (p = 0.038) and LVEF 3D (p = 0.003). For the GLS parameter, there was a lower average GLS in the RV apical lead group, with this difference being significantly different from that in the RVOT lead group (p = 0.031).

Figure 2 presents an example of a 3D LVEF report and GLS obtained from the echocardiography machine used in this study. Based on the validation study, the average normal value of 3D GLS reported in the study ranged from –15.80% to –23.40%, and the normal range of 3D GLS was from –15.50% to –39.50%.[17] Based on the American Society of Echocardiography (ASE) Recommendations for Cardiac Chamber Quantification in Adults in 2015, the normal range of LVEF BIPLANE values is 53–73% in the population; thus, an LVEF BIPLANE value <53% is categorized as LV dysfunction.[17] From the results of the sample analysis, it was found that 10 patients (27%) in the RV apex lead group experienced LV dysfunction, whereas in the RVOT lead group, only one patient (5%) experienced a decrease in LVEF <53%, where this difference was sig-

Table 2 – Comparison of LV Systolic Function According to RV Apex and RVOT Lead Placement after PPM Implantation

Variable	Lead	Mean (SD)	Median (min–max)	*p*-value
LVEF A2C	RVOT Apical	64.81 (5.12) 59.30 (8.77)	65 (55–73) 61 (38–75)	0.029
LVEF A4C	RVOT Apical	63.77 (6.08) 58.92 (9.68)	70 (35–85) 71 (28–83)	0.038
GLS 3D	RVOT Apical	–19.80 (3.82) –17.53 (2.83)	19.75 (15.20–27.80) 17.25 (13.40–25.40)	0.031
LVEF 3D	RVOT Apical	63.52 (4.89) 56.89 (5.88)	63.60 (56.90–74.90) 56.95 (46.90–66.80)	0.003

3D – three dimensional; GLS – global longitudinal strain; LVEF – left ventricular ejection fraction; SD – standard deviation.

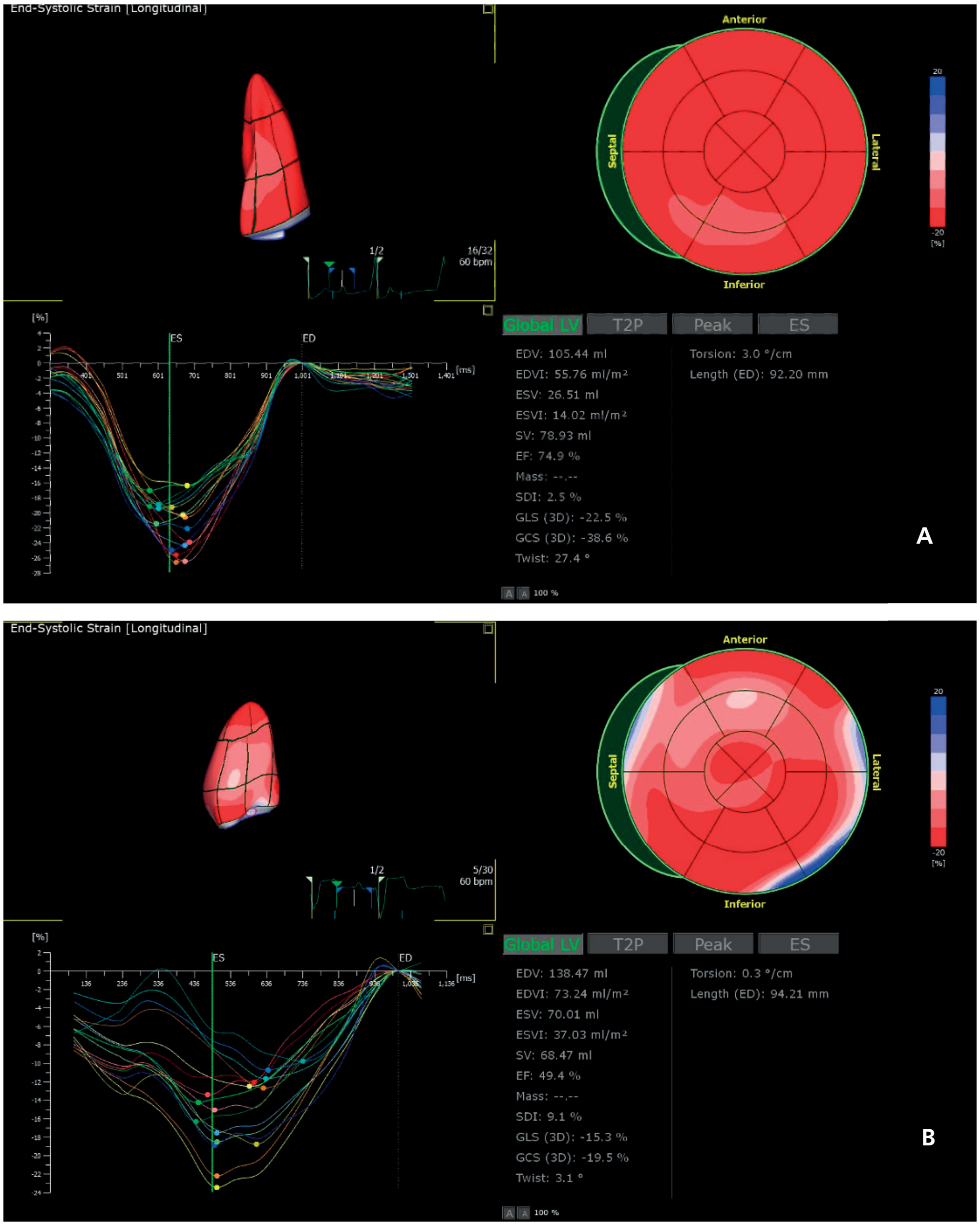

Fig. 2 – Three-dimensional echocardiography reports including EDV, ESV, SV, LVEF, GLS, and GCS. (A) 3D echocardiography report of a patient with an RV pacing lead RVOT; (B) 3D echocardiography report of an RV pacing patient with a lead in the RV apex. This feature demonstrates several advantages over BIPLANE LVEF, including improved accuracy in assessing cardiac volume and more comprehensive visualization. In this image, the average LVEF value for the RVOT group is notably higher than the LVEF (>53%).
EDV – end-diastolic volume; EDVI – end-diastolic volume index; ESV – end-systolic volume; ESVI – end-systolic volume index; GCS – global circumferential strain; GLS – global longitudinal strain; LVEF – left ventricular ejection fraction; SV – stroke volume.

nificant ($p = 0.011$). From the results of the characteristics of the research samples, there was one characteristic with a significantly different distribution, namely gender.

Comparison between the RV apex pacing vs. RVOT with the occurrence of left ventricular dilatation

Measurement of left ventricular size in the pacemaker sample population based on similar studies uses the LVEDd method and volume measurements (EDV and EDS). Based on the ASE Recommendations for Cardiac Chamber Quantification in Adults in 2015, the normal range of LVEDd values in men is 4.2–5.8 cm and in women it is 3.8–5.2 cm, LV end-diastolic volume (LV EDV-2D) in men is 62–150 mL and in women is 46–106 mL, then LV EDV values >150 mL in men and 106 mL in women are categorized as LV dilation. The normal range of LV end-systolic volume (LV ESV-2D) in men is 21–61 mL and in women it is 12–42 mL, so LV ESV values >61 mL in men and 42 mL in women are categorized as LV dilation.[18] From the results of the sample analysis, only one parameter was significantly different, namely

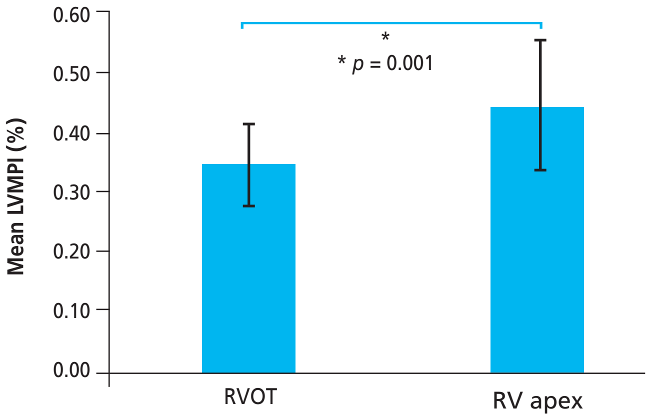

Fig. 3 – Comparison of LVMPI between both lead groups after PPM implantation. The comparison of Left Ventricular Myocardial Performance Index (LVMPI) between the two lead groups after PPM implantation revealed that the RVOT group (0.35 ± 0.07) had a significantly lower LVMPI than the RV apex group (0.45 ± 0.11). LVMPI assesses the efficiency of the heart by measuring the time required for left ventricular contraction and relaxation. The increase in LVMPI values for the RV apex group, exceeding normal levels as shown in the figure, indicates potential cardiac dysfunction.

the LVEDd value in men, obtained in the RV apex pacing group, a larger LVEDd was obtained (4.90 ± 0.44 cm) than the RVOT lead (4.17 ± 0.39 cm, $p = 0.01$), but none of them experienced LV dilation, and differences in EDV and ESV parameters between groups were not significant (**Table 3**). Based on the normal range values of the ASE Recommendations for Cardiac Chamber Quantification in Adults, 6 out of 56 total patients experienced LV dilatation, among whom one was from the RVOT lead group and five were from the RV apex lead group, but no significant difference was observed between the two groups ($p = 0.155$).

Comparison between the RV apex pacing vs. RVOT with the occurrence of a decrease in the Left Ventricular Myocardial Performance Index

The LVMPI is a parameter that can assess the systolic and diastolic ability of the myocardium in one parameter, namely the measurement of the mitral valve and left ventricular outflow tract flow. The normal value range of LVMPI is 0.38 ± 0.05.[19] This study showed that there was a significant difference ($p = 0.001$) in LVMPI between the RV apex lead and RVOT, with LVMPI in the RV apex lead group of 0.45 ± 0.11 and that in the RVOT lead group of 0.35 ± 0.07, as shown in **Figure 3**.

Discussion

The rate of PPM implantation increases with age, with an estimated 70–80% of all PPMs implanted in patients older than 65 years.[20] Old age is a predictor of the incidence of symptomatic heart failure among pacemakers undergoing RV pacing.[21] The mean age was similar to that of most of the other studies (68.16 years). The main indication for PPM implantation in Asia is total AV block (TAVB), whereas sinus node dysfunction (SND) is more prevalent in Western countries.[22,23] This is also similar to the indications for PPM implantation in this study population, with the highest PPM implantation indication for both lead groups being TAVB (71.4%), followed by high-degree AV block, and SND. This study also considered hypertension and diabetes mellitus as comorbidities and history of anti-remodelling drug use, which could be confounding factors. However, there were no significant effects of these factors on the analysis; thus, multivariate testing was not performed. This study found that there was one characteristic with a significantly different distribution, namely gender. Our analysis showed that this did not affect the difference in LV dysfunction between the groups. However, one study noted that males are more susceptible to PiCMP and the development of hypertrophic cardiomyopathy.[24] Further research is needed to understand the effects of sex on LV dysfunction and changes in cardiac structure.

RV pacing has a pathophysiological mechanism similar to that of LBBB, causing delayed activation of the LV free wall and electromechanical dyssynchrony. At the cellular level, RV pacing induces changes in LV apoptosis pathways and calcium handling. Although transseptal conduction time is slower than LBBB and RV pacing can create heterogeneity in wavefront propagation, it still causes significant hemodynamic disturbances and heart failure.[25]

Table 3 – Comparison of left ventricular dimension parameters based on RV apex and RVOT lead placement after PPM implantation

Variable	Lead	Mean (SD)	Median (min–max)	*p*-value
LVEDd Men	RVOT Apex	4.17(0.39) 4.90(0.44)	4.10 (3.60–4.90) 4.90 (4.20–5.50)	0.01
LVEDd Women	RVOT Apex	4.15 (0.23) 4.34 (0.74)	4.10 (3.80–4.50) 4.50 (2.70–5.60)	0.246
EDV 2D Men	RVOT Apex	43.83 (26.04) 40.36 (9.54)	40.2(21.61–108.8) 43.2(21.41–49.17)	0.725
EDV 2D Women	RVOT Apex	35.60 (13.24) 34.93 (12.19)	30.77 (25.29–65.81) 33.60 (15.59–61.23)	0.895
ESV 2D Men	RVOT Apex	16.14 (7.79) 17.7 (7.97)	14.96 (7.47–29.80) 15.77 (9.01–34.77)	0.655
ESV 2D Women	RVOT Apex	13.55 (6.64) 14.57 (7.25)	14.12 (11.29–27.80) 13.40 (11.26–33.26)	0.487

2D – two dimensional; LVEDd – left ventricle end-diastolic diameter; SD – standard deviation.

Electromechanical coupling allows the ventricular activation to start from the apex and extend toward the heart base.[26] However, during RV apex pacing, the propagation of the electrical impulse is not through pacemaker cells but rather from non-specific myocardial cells; thus, it is slower. This phenomenon causes different directions of electrical activation, resulting in inter- and intraventricular dyssynchrony and QRS duration prolongation.[27] This dyssynchrony will also cause less effective contraction, which can lead to LV remodelling, dilation, asymmetric hypertrophy, and functional mitral regurgitation, which will increase the risk of LV systolic dysfunction, heart failure, and atrial fibrillation.[6,28,29] RVOT septal pacing has the shortest QRS duration and the most effective lead-site test results, making it a better choice for chronic RV pacing because it is associated with improved LV dynamics and involves the Purkinje network earlier.[6] However, to date, there is no clear evidence showing the clinical benefits of alternative RV pacing sites.

In this study, the use of ejection fraction parameters with the modified Simpson's method (BIPLANE) showed that LVEF significantly decreased after PPM implantation in the RV apex lead group. These results are in line with several other studies that noted a significant decrease in LVEF in the RV apex lead group after 2 years and other studies that reported better LVEF and NT-proBNP results in the RVOT lead group.[11,30] A previous study also showed the superiority of RVOT leads in improving myocardial perfusion defects compared with RV apex leads. However, Stambler et al., 2003 did not find significant differences in LVEF and quality of life between patients with RV apex and RVOT leads after 9 months of implantation, which may be due to the inclusion of patients with chronic atrial fibrillation and previous LV dysfunction in the study.[11,30–32]

In addition to LVEF BIPLANE, this study validated LV systolic function using several other parameters, including LVEF A2C, LVEF A4C, GLS 3D, and LVEF 3D. Significant differences in LVEF A2C and A4C parameters were predicted because the measurement of LVEF BIPLANE parameters is a combination of these two LVEFs. The 3D calculation of LVEF is a more accurate and objective parameter for measuring the decline in LV systolic function. This study found significant differences between the RV apex and RVOT lead groups, with 27% of patients in the apical lead group experiencing LV dysfunction, whereas no patient in the RVOT group had LVEF <53%. The average GLS was also lower in the RV apex lead group than in the RVOT group, although both groups remained within the normal range.[17] Other studies have shown a significant decrease in 3D LVEF in this population and a negative impact of RV apex pacing on LV synchrony and mechanics. Lower LV peak GLS is associated with a higher risk of developing PiCMP.[20,33,34]

This study also analysed the relationship between RV apex and RVOT lead positions and the incidence of LV dilatation using left ventricular size measurement methods, such as LVEDd, EDV, and ESV. The analysis showed that in the apical RV pacing group, male LVEDd was larger, but there was no LV dilatation. A previous study found no significant difference in EDV before and 6 months after implantation, although ESV showed significant dilatation after 7 days. Ventricular dyssynchrony due to RV pacing can cause structural changes in the myocardium, such as asymmetric hypertrophy and LV dilatation.[20,35] Other researchers have reported increased LVEDd in patients receiving long-term apical RV pacing, whereas most patients did not experience symptoms of heart failure after 20 years.[36]

The last parameter analysed in this study was the relationship between the position of the RV apex and RVOT leads with LVMPI. LVMPI is used to assess myocardial systolic and diastolic ability in one parameter (with measurements of the mitral valve and left ventricular outflow tract flow). This study showed a significant difference in LVMPI between the RV apex and RVOT leads, with the LVMPI value in the RV apex lead group being 0.45 ± 0.11, indicating low cardiac performance in the RV apex lead group. A similar study found that RV apex pacing was associated with decreased LV pressure change rate and ventricular contraction dyssynchrony, which negatively affected stroke volume and LV diastolic function. The results showed a significant difference in LVMPI, where the RV apex lead had lower cardiac performance (0.45 ± 0.11) than the RVOT.[37] Another study reported a higher mean MPI in the RV apex pacing group (0.46 ± 0.12) compared to the control.[38] In addition, a study noted impaired LV function in patients receiving apical RV pacing after 10 years. The 'triple control of relaxation' theory explains that contraction dyssynchrony due to RV apex pacing can interfere with ventricular relaxation, causing diastolic dysfunction.[39]

Conclusion

There is a significant difference between the implantation of PPM with RV apex pacing compared to RVOT and the incidence of left ventricular systolic dysfunction, left ventricular dilatation, and left ventricular myocardial performance index after 2 years of implantation. There are several weaknesses in this study, one of which is the small sample size, and it was conducted at a single center. The echocardiography machines and operators involved in measuring pre-implantation samples and post-implantation evaluations are different, which can cause bias. In addition, the pacemaker brands used in this study were not the same, which can also cause bias due to differences in modality. Similar studies need to be conducted by increasing the number of samples and developed at the multicentre level to strengthen the significance of the study. Further research with an RCT or prospective cohort design will strengthen the results of this study. The comparison of RV pacing with left bundle branch pacing or his bundle pacing also represents a promising prospective study for the future, as the procedure has demonstrated superior protection of LV function in various recent studies, although its implementation presents its own challenges. Routine LV evaluation through echocardiography in all recipients of single-chamber RV pacing PPM implantation by performing echocardiography once a year can also show the effect of wider PPM lead placement and, most importantly, can detect early LV dysfunction or remodelling.

Conflict of interest
The authors declare that they have no conflict of interest in the conduct and reporting of this study.

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None to declare.

Ethical statement
The study protocol was approved by the ethics committee of Dr. Soetomo Hospital, Surabaya, Indonesia (protocol number: 0477/KEPK/IX/2022).

Informed consent
All patients provided written informed consent to participate in the study.

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