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Original Article

The effect of biventricular pacing on cardiac function after open heart surgery

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Abstract

Background: Temporary postoperative pacing could enhance recovery of the cardiac function. The right ventricular pacing (RV) is commonly used, but it can cause dyssynchronous contraction of both ventricles. Biventricular pacing (BV) could improve the systolic function by synchronizing the ventricular contraction. The aim of this study is to evaluate the effectiveness of biventricular pacing in improving the hemodynamics in the early postoperative period compared to other pacing modes.

Methods: This is a clinical crossover trial including 50 patients who underwent open cardiac surgery in the period from September 2017 to September 2018. Mean age was 46.78± 12.09 years, and 50% were males. Temporary pacing leads were attached to the anterior wall of the right ventricle 1-2 cm paraseptally and the lateral wall of left ventricle 1-2 cm paraseptally. Each patient was paced for 3 minutes in the first 1-4 postoperative hours with 20 minutes washout period between different pacing modes. Study endpoints included cardiac output, ejection fraction (EF) and wall motion abnormality.

Results: Biventricular and right ventricular pacing increased postoperative cardiac output (6.31± 1.28 and 5.2±0.72 L/min; respectively), but BV pacing was superior to RV pacing (P-value <0.001). The effect of BV pacing was more evident in patients with EF < 50% (7.27± 0.895 vs. 5.26 ± 0.634 L/min; p< 0.001). The postoperative EF improved during BV pacing (53.16± 4.71%) compared to RV pacing (49.4± 4.07%; P-value <0.001). Both BV and RV pacing were associated with less paradoxical septal wall motion abnormality (P-value <0.001).

Conclusions: Temporary postoperative biventricular pacing improves hemodynamics compared to right ventricular and no pacing. Routine BV pacing is recommended especially in patients with low ejection fraction.

KEYWORDS
Biventricular pacing; Open heart surgery; Cardiac output; Cardiac index

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Introduction

The early postoperative period after cardiac surgery is very crucial, and it may require the institution of circulatory assist devices, or temporary cardiac pacing [1]. Temporary cardiac pacing was routinely used in cardiac surgery since 1960 for therapeutic and diagnostic purposes [2,3]. It can affect the recovery of the cardiac function by maintaining heart rate and rhythm which are necessary to optimize hemodynamics

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and to suppress both atrial and ventricular tachyarrhythmias without increasing myocardial oxygen consumption [4,5].

Temporary epicardial pacemakers have evolved from simple single chamber devices with few programmable parameters to sophisticated dual chamber devices with adjustable parameters similar to permanent pacemakers [6]. Generally, the ventricular electrodes are placed in the right ventricle (RV), but the ideal site for pacing is still debatable. RV pacing can treat the arrhythmic complications, but it does not induce physiologic activation of the left ventricle (LV) leading to the asynchronous ventricular contraction that impacts the contractility and efficiency of the LV [7].

The use of biventricular pacing (BV) may have a positive effect on hemodynamics immediately after weaning from cardiopulmonary bypass (CPB) and in the early postoperative period [8]. Therefore, the aim of this study was to evaluate the effectiveness of BV pacing in improving hemodynamics and wall motions in early postoperative period compared to other pacing modes.

Patients and Methods:

Study design:

This is a clinical crossover trial including 50 patients recruited from the Cardiothoracic Surgery Department, Tanta University Hospitals. Patients underwent open cardiac surgery in a period from September 2017 to September 2018. The study was approved by the Ethical Committee, and patients' consent was obtained prior to participation.

Inclusion and exclusion criteria:

All patients were above 18 years old and had preoperative atrial fibrillation (AF). We excluded patients below 18 years old and patients with congenital heart disease, permanent pacemaker or implantable cardioverter defibrillator system. Patients with preoperative end organ failure such as renal failure, dilated cardiomyopathy or congestive heart failure were not included. Additionally, patients unable to provide written, informed consent or already participating in another clinical trial were excluded. Postoperative hemodynamic instability; defined as the need for intra-aortic balloon pump (IABP) or high inotrope dosage; were excluded because of their effect on measuring the study endpoints.

Table 1: Preoperative patients' characteristics. Continuous variables are presented as mean± SD and Binary variables as number and percent.

Variable	N=50
Age (years)	46.78± 12.09
Male	25 (50%)
BSA (m2)	1.72± 0.19
Diabetes Mellitus	4 (8%)
RHD	31 (62%)
COPD	2 (4%)
Hypercholesterolemia	7 (14%)
Previous cardiac surgery	3 (6%)
ESD	38.053± 9.06
EDD	56.036± 9.93
Wall motion abnormality	6 (12%)
LA diameter (mm)	47.1± 10.39
EF (%)	52.6± 9.16
Heart rate (b/min)	75.52± 13.81
QRS (ms)	116.4± 21.6

Continuous data are presented as mean± SD and binary data as number and percent. BSA: Body Surface Area; COPD: Chronic Obstructive Pulmonary Disease; EDD: End-diastolic diameter; ESD: End-systolic diameter; RHD: Rheumatic Heart Disease.

Data collection, pacing technique, and study endpoints:

Preoperative routine workup was done including full history taking and clinical examination, ECG and echocardiography. Intraoperative data included: type of operation (either coronary artery bypass grafting, valve surgery or combined), bypass time and cross-clamp time. All interventions were performed using the cardiopulmonary bypass, and myocardial protection was achieved using cold crystalloid cardioplegia. The patients were cooled to 32°C, and perfusion pressure was maintained in the range of 60–70 mmHg. Temporary epicardial unipolar pacing leads were attached before separation from CPB to the anterior wall of the right ventricle 1-2 cm paraseptally, and to the lateral wall of left ventricle 1-2 cm paraseptally,

Table 2: Operative data. Continuous variables are presented as mean± SD and categorical variables as number and percent.

Variable	N=50
Operation Performed	
Valve surgery	37 (74%)
CABG	11 (22%)
Combined valve and CABG	2 (4%)
CPB time (minutes)	116.9± 45
Ischemic time (minutes)	88.87± 39.34

CABG: Coronary Artery Bypass Grafting; CPB: Cardiopulmonary Bypass.

and two leads were stitched to the skin. All patients were evaluated without pacing as the control group then patients had right and biventricular pacing within the first 1-4 hours after surgery. Each patient was paced for 3 minutes in the ICU using each of the pacing modes and the native rhythm. Then after 20 minutes "washout period," the pacing mode was changed. Study endpoints were postoperative cardiac output (COP), ejection fraction (EF), QRS duration, and septal wall motion changes.

The postoperative intensive care was standardized and weaning from mechanical ventilation was performed in hemodynamically stable patients after the restoration of consciousness and muscle power. Intravenous drug infusions and inotrope doses were not changed during the measurements. The inotropes used postoperatively in our study included milrinone, dobutamine, adrenaline, and noradrenaline (administered to maintain a MAP of 60-70mmHg). Patients with AF rhythm had amiodarone infusion if needed to control heart rate below 90 beats per minute. Dual chamber temporary pacemaker (Medtronic 5392, Minneapolis, MN, USA) was used in all patients.

COP was measured by the thermal dilution method using a Swan-Ganz catheter. Five cardiac outputs were measured. The highest and lowest were discarded, and the remaining three were averaged and divided by body surface area to determine the cardiac index. Transthoracic echocardiography was used to estimate septal wall motion and EF by one cardiologist.

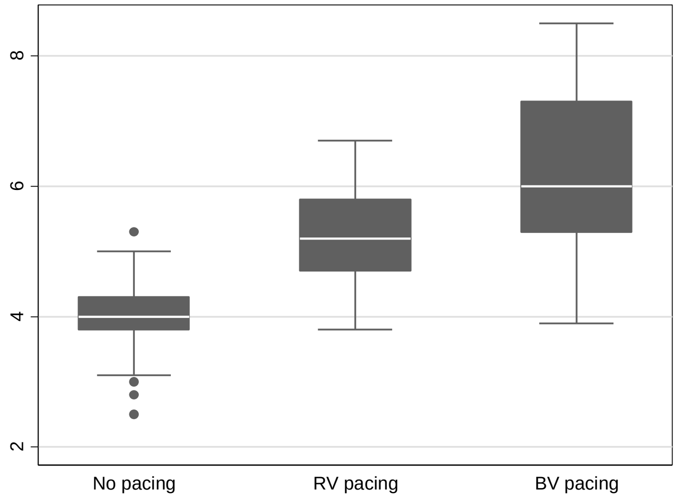

Figure 1: Boxplot for the change in COP after right ventricular and biventricular pacing. (BV: Biventricular; COP: Cardiac Output; RV: Right Ventricular).

Statistical analysis

Statistical presentation and analysis of the present study were conducted using SPSS V17 (IBM Corporation, Chicago, IL, USA). Continuous data were presented as mean± standard deviation and binary data as number and percentage. Shapiro Wilk test was used to assess the normality distribution for continuous variables. Friedman was used to compare the three groups. Wilcoxon matched pair sign rank test was used for comparison of the nonparametric continuous variables between each two pacing modes. Cochran and McNemar's tests were used to compare binary data.

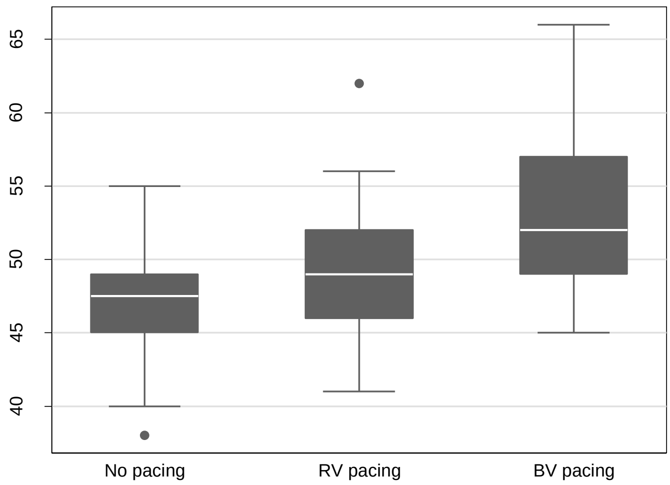

Figure 2: Boxplot for the change in ejection fraction after right ventricular and biventricular pacing. (BV: Biventricular; RV: Right Ventricular)

A p-value of less than 0.05 is considered statistically significant. A total number of 42 is required to detect an increase in COP by 0.25 l/min in each group with 80% power and 0.05 alpha error.

Results

The mean age of 46.78± 12.09 years and 50% (n= 25) of patients were males. Table 1 shows the preoperative patients' characteristics. Preoperative echocardiography data were preoperative end-systolic diameter (ESD) (38.053± 9.06 mm), end-diastolic diameter (EDD) (56.036± 9.93 mm), and the ejection fraction (52.6± 9.16%). Valve surgery was the most common surgical procedure performed in 37 patients (74%). The mean cross-clamping time was 88.87± 39.34 minutes and the cardiopulmonary bypass time was 116.9± 45 minutes (Table 2).

The three pacing modes (no pacing, RV pacing, and BV pacing) were compared postoperatively in the same patients. Postoperative cardiac output improved significantly after both RV and BV pacing compared to no pacing (6.31± 1.28 and 5.2 ±0.72 L/min; p< 0.001) (Table 3, Figure 1). The effect of BV pacing was more evident in patients with EF < 50% (7.27± 0.895 vs. 5.26 ± 0.634 L/min; p< 0.001) Ejection fraction improved significantly with BV pacing (53.16± 4.71%) compared to RV pacing (49.4± 4.07%) and no pacing (47.14± 3.42 %) (p< 0.001). (Figure 2) The effect of BV pacing was more prominent in patients with EF< 50% (55.23± 4.02 vs. 50.917± 4.43 %; p< 0.001). The cardiac index

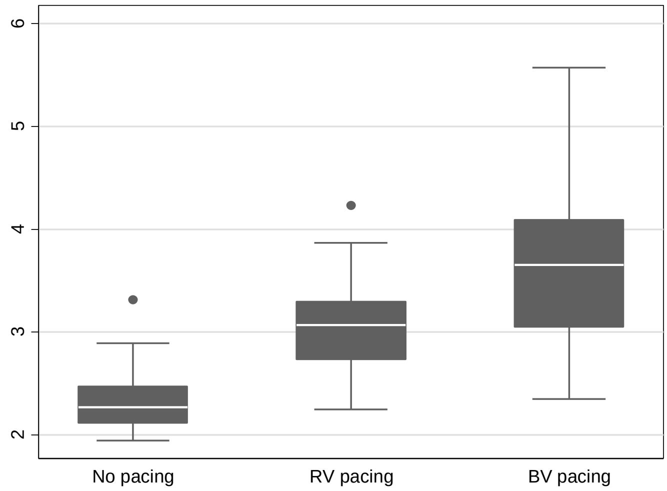

Figure 3: Boxplot for the change in ejection fraction after right ventricular and biventricular pacing. (BV: Biventricular; COP: Cardiac Output; RV: Right Ventricular)

improved significantly with RV and BV pacing (p<0.001) (Figure 3). Wall motion improved significantly with RV and BV pacing compared to no pacing (p< 0.001), but there was no statistically significant difference between RV and BV pacing (p>0.99) (Table 3). QRS duration decreased significantly after BV pacing (82.4± 7.58 ms) compared to RV pacing (96.3± 11.9 ms; p< 0.001) and no pacing (110.5± 16.89 ms; p< 0.001) (Table 3).

Discussion

The benefits of BV pacing in patients with low EF are well established; however, there is little data on its effect after cardiac surgery [9].

Table 3: Outcomes of pacing. Continuous variables are presented as mean± SD and binary variables as number and percent.

	No pacing	RV pacing	BV pacing	p-value
COP (L/min)	4 ± 0.54 P1-2 < 0.001	5.2 ± 0.72 P2-3 < 0.001	6.31 ± 1.28 P1-3 < 0.001	<0.001
CI (L/min/m2)	2.34 ± 0.31 P1-2 < 0.001	3.04 ± 0.42 P2-3 < 0.001	3.68 ± 0.73 P1-3 < 0.001	<0.001
EF (%)	47.14 ± 3.42 P1-2 < 0.001	49.4 ± 4.07 P2-3 < 0.001	53.16 ± 4.71 P1-3 < 0.001	<0.001
Wall motion abnormality	32 (64%) P1-2 < 0.001	8 (16%) P2-3 > 0.99	8 (16%) P1-3 < 0.001	<0.001
QRS (ms)	110.5 ± 16.89 P1-2 < 0.001	96.3 ± 11.9 P2-3 < 0.001	82.4 ± 7.58 P1-3 < 0.001	<0.001

CI: Cardiac Index; BV: Biventricular; COP: Cardiac Output; EF: Ejection Fraction; RV: Right Ventricle; P1: no pacing, P2: RV pacing, P3: BV pacing

In this study, we assessed the effect of biventricular pacing in improving hemodynamics in the early postoperative period compared with other modes of pacing.

Our study population included 50 adult patients who underwent CABG or valve surgery, and the different modes of pacing were compared in the same patient. It was recommended by Dickstein and colleagues [10] that patients with QRS ≥120 ms with signs of desynchrony post cardiac surgery require BV pacing. The mean preoperative QRS in our patients was 116.4± 21.6 ms which lies below the recommended indications for BV pacing. Despite that, results of BV pacing were superior compared to other modes, and this could be due to the desynchrony that can occur intraoperatively or postoperatively in the form of paradoxical septal motion even with the presence of preoperative normal QRS duration [11].

BV and RV pacing improved the postoperative COP, cardiac index, EF and wall motions compared to no pacing. The improvement in COP was higher with BV pacing. In consistency with our results, Foster and colleagues [12] compared BV pacing and no pacing and found that BV pacing increased the COP significantly. Dzemali and associated [11] and Garcia and colleagues [13] compared BV pacing and no pacing and concluded that COP was higher with BV pacing ($p < 0.01$ and <0.05 respectively). Another study [14] compared BV with RV pacing and showed that COP was increased significantly with BV pacing ($p<0.001$). The improvement in COP with BV pacing could be attributed to the synchronous ventricular contraction with its effect on increasing LV contraction and stroke volume.

On the other hand, Muehlschlegel [9] and Gielgens and their colleagues [8] compared BV and RV pacing and found no significant difference between them (P= 0.3 and 0.875 respectively). This non-significant difference can be explained with the fixed heart rate on both pacing modalities with a lower EF in the RV pacing group [9]. In our study, patients served as their own control which abolishes the baseline difference in patients' characteristics.

Postoperative EF significantly increased with BV pacing versus RV and no pacing ($P<0.001$). In consistency with our results, Muehlschlegel and associates [9] found a significant increase in EF with BV pacing (44±12%) compared to RV pacing (36±14%). BV pacing could lead to optimization of the timing interval between atrial and ventricular contraction and restoration of cardiac resynchronization that will optimize the diastolic filling period and increase EF [15,16]. An alternative mechanism is the ''interventricular assist'' which means that BV pacing can recruit the unstressed ventricle to support the function of the failing one by bringing pressure work from the less compromised ventricle to the distressed ventricle that finally improves EF, but this theory needs further investigation [13,17]. RV pacing induces right ventricular contraction before the LV which diminishes the output of the ventricles [9].

This study confirmed the superiority of BV pacing in improving postoperative hemodynamics in patients undergoing CABG or valve surgery compared to RV or no pacing and its routine use and expansion its application to more subgroups are recommended.

Study limitations:

The major limitation of the study is the single center experience which limits the generalization of the findings and the results to different populations. Wall motion abnormality was assessed using transthoracic echocardiography which is a subjective method. Transesophageal modalities which incorporate tissue doppler imaging that estimates regional wall contraction may further define the value of resynchronization at all ventricular segments. We used dual chamber temporary pacemaker with some modifications to be suitable for BV pacing. However, it is recommended to use triple chamber temporary external pacemaker whenever possible.

Conclusion

Temporary biventricular pacing is effective in improving cardiac output and ejection fraction compared to other pacing modalities after cardiac surgery. Routine postoperative biventricular pacing is recommended especially in patients with low ejection fraction.

Conflict of interest: Authors declare no conflict of interest.

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