Temporary left ventricular pacing improves haemodynamic performance in patients requiring epicardial pacing post cardiac surgery

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Abstract

Objective: In the 1990s, sequential atrio-ventricular pacing demonstrated haemodynamic benefit relative to right ventricular pacing in patients with sinus rhythm requiring pacing post cardiopulmonary bypass. The benefit of biventricular pacing has been demonstrated in non-surgical patients with severe left ventricular dysfunction. It was hypothesised that left ventricular pacing would increase cardiac output in surgical patients. We report the findings of a prospective trial of left ventricular pacing with active lead placement on the anterior or posterior left ventricular surface, compared to standard practice of active lead placement on the right ventricular surface.

Methods: Twenty five patients with left ventricular dysfunction underwent pacing with active lead placement on the right ventricle (control), the anterior left ventricle and the posterior left ventricle in random order, with each pacing mode of 10 min duration, following cardiopulmonary bypass. Haemodynamic parameters were measured with a thermodilution pulmonary artery catheter. Patients provided their control values.

Results: In the 25 patients studied, pacing with the active lead posteriorly on the left ventricle increased cardiac index from 2.74 to 3.08 l/min per m² (P < 0.019). Significant increases in mean arterial pressure with the use of this pacing mode were observed. There were no complications relating to application or removal of the left ventricle pacing leads.

Conclusions: Left ventricular pacing with active lead placed on the postero-lateral left ventricular wall affords haemodynamic benefit to cardiac surgical patients.

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1. Introduction

Epicardial pacing is commonly indicated in cardiac surgical patients using right ventricular (RV) and/or right atrial (RA) pacing wires. In patients in sinus rhythm (SR), two RA and two RV epicardial wires are attached, resulting in dual chamber or sequential atrio-ventricular pacing (DDD). Patients with atrial fibrillation (AF) receive only RV pacing wires, which traditionally have been used due to ease of application to the anterior wall of the RV, prior to separation from cardiopulmonary bypass.

The benefit of cardiac re-synchronization therapy (CRT) in heart failure has been demonstrated. The Pacing Therapies for Congestive Heart Failure [PATH-CHF] study [1,2] has demonstrated the advantageous haemodynamics of CRT in patients with severe LV dysfunction. This study assessed the effects of biventricular, LV and RV pacing, applied in atrio-ventricular mode in a multicentre study of 39 patients under general anaesthesia. Both biventricular and LV modes significantly increased LV dP/dt and aortic pulse pressure relative to RV pacing [1,2]. Similarly, the MULTISITE Stimulation Cardiomyopathy [MUSTIC] study [3] has demonstrated a significant improvement in LVEF and patient symptoms after 12 months of biventricular pacing in 131 heart failure patients.

It is recognized that RV stimulation worsens LV systolic function compared with normal activation [4], with the results being less detrimental for LV or biventricular pacing [5] in normal hearts. Endocardial mapping studies have shown that these effects are exacerbated in patients with structural heart disease and that the haemodynamic results of RV pacing depend upon the site of LV myocardial pathology [6]. The pathophysiologic effects of RV pacing include prolonged isovolumetric contraction and relaxation resulting in reduced LV filling; prolonged systolic action, resulting in an exacerbation of functional mitral regurgitation, and paradoxical septal motion due to initial RV activation. While similar haemodynamic performance has been described in patients with LV dysfunction and left bundle branch block, RV pacing has distinct LV activation and haemodynamic properties [7]. The predominant haemodynamic advantages of biventricular pacing upon LV function are predominantly determined by LV pacing, with or without concurrent RV activation [2,8].

Minimal data exist regarding LV or biventricular pacing in surgical patients [9,10]. Foster and co-workers studied the effects of biventricular (DDD) pacing in comparison to atrial pacing (AAI), RV (DDD) and LV (DDD) pacing modes in
18 elective coronary artery bypass patients, of whom 14 had LV ejection fractions (LVEF) of over 40%. Biventricular pacing was associated with a significant increase in cardiac index (CI) relative to all other pacing modes studied. Different sites of LV lead placement were not studied in this work [9]. Cardiac surgical patients with left or right ventricular dysfunction or patients with inherent aberrant conduction may derive peri-operative clinical benefit from pacing of both LV and RV in the early post-operative period, compared to standard practice [10].

Regardless of electrocardiographic evidence of dys-synchronization, LV pacing may offer improved haemodynamic performance, relative to RV pacing following cardiac surgery. We hypothesised that LV pacing, with active lead placement on the LV (atrio-ventricular mode for patients in SR) would increase CI, relative to standard RV pacing. The aim of this short-term haemodynamic study was to perform a prospective randomized controlled clinical trial to assess the potential benefits of LV pacing in comparison to RV pacing in the early post-operative period in patients that require pacing post cardiac surgery.

2. Materials and methods

Enrollment criteria for this study included any adult patient undergoing cardiac surgery with cardiopulmonary bypass, who required a Swan-Ganz catheter for early post-op management and pacing post-operatively. Exclusion criteria included the presence of a permanent pacing system or patients undergoing cardiac transplantation. Local institutional ethical committee approval was obtained and all patients gave fully informed written consent.

Preoperative ECG details were noted, including rhythm, QRS duration and aberrant conduction. Preoperative rhythm was defined as SR or AF. Risk stratification was performed with the Euroscore [11] and Parsonnet systems [12]. LVEF was derived from ventriculography at left heart catheterization.

Following the completion of the relevant cardiac surgical procedure and prior to separation from CPB, epicardial pacing wires (Sorin Biomedica, Harrogate, UK) were placed. The RA and RV leads were sutured to the standard epicardial sites and the leads passed percutaneously and sutured to the skin to the right and left of the lower extent of the sternotomy skin incision, respectively. Two separate LV epicardial leads were then placed. The first or anterior LV lead (LVA) was placed immediately to the left of the point of the left anterior descending coronary artery (LAD) and this was passed percutaneously, lateral to the RV leads. The second or posterior LV lead (LVP) was placed in the epicardium of the LV lateral or free wall one centimetre from where the distal circumflex coronary artery branches emanate from the A-V groove. This wire was passed percutaneously, lateral to the LVA lead.

All patients had a Swan-Ganz pulmonary arterial thermodilution catheter floated for clinical indications (Baxter, Inc., Orange County, CA, USA). The pacing rate was set at 90 beats/min, using dual chamber pacing for SR patients with an AV delay of 120 ms. The following pacing modes were studied in randomized order:

1. Atrio-RV pacing: Active and inactive (negative and positive) leads were placed upon the right atrium and similarly on the anterior RV surface.
2. Atrio-left ventricular anterior pacing (LVA): Active and inactive right atrial leads were placed as before. The active LV lead (negative) was the lead placed immediately left of the mid LAD, with the inactive lead (positive) taken as one of the RV leads.
3. Atrio-left ventricular posterior pacing (LVP): Active and inactive atrial leads were placed as before. The active atrial lead (negative) was taken as the posterior LV lead described above (placed in the free or lateral LV wall, in the region of the distal circumflex vessels), with the inactive lead being a right ventricular lead.

Upon return to cardiac intensive care, after 1 h of haemodynamic stability, without excessive bleeding, minimal intravascular volume change, no inotropic changes and patient sedation, the above pacing modes were studied. The order of pacing modes was randomized. All patients underwent 10 min each of RV, LVA and LVP pacing modes. After 10 min of each mode, CI, mean arterial pressure (MAP), pulmonary artery wedge pressure (PAWP), mean pulmonary arterial pressure (MPAP) and central venous pressure (CVP) were measured. Systemic vascular resistance (SVR), systemic vascular resistance index (SVRI), pulmonary vascular resistance (PVR), pulmonary vascular resistance index (PVRI) and left ventricular stroke work index (LVSWI) were derived (Datex Ohmeda, Hatfield, UK). Each patient underwent all three pacing modes, thus providing their controls (RV). All epicardial pacing leads were removed on the day prior to hospital discharge.

Statistical analysis was performed with the paired t-test using SPSS software (SPSS, Inc., Illinois, USA). A P-value of less than 0.05 was taken as statistically significant and the results were analysed as an overall group (n = 25), the SR patient sub-group (n = 20) and the AF patient sub-group (n = 5).

Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Result (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>69.88 ± 8.55</td>
</tr>
<tr>
<td>Male:female</td>
<td>20:05</td>
</tr>
<tr>
<td>Euroscore (±SD)</td>
<td>7.23 ± 2.64</td>
</tr>
<tr>
<td>Parsonnet score (±SD)</td>
<td>15.18 ± 9.39</td>
</tr>
<tr>
<td>Operative procedure (%)</td>
<td></td>
</tr>
<tr>
<td>CABG</td>
<td>Nine patients (36%)</td>
</tr>
<tr>
<td>Redo CABG</td>
<td>One patient (4%)</td>
</tr>
<tr>
<td>LV aneurysmorrhaphy/CABG</td>
<td>One patient (4%)</td>
</tr>
<tr>
<td>AVR</td>
<td>One patient (4%)</td>
</tr>
<tr>
<td>AVR+ CAGB</td>
<td>Five patients (20%)</td>
</tr>
<tr>
<td>MV repair</td>
<td>Two patients (8%)</td>
</tr>
<tr>
<td>MVR</td>
<td>Four patients (16%)</td>
</tr>
<tr>
<td>MVR+ CAGB</td>
<td>One patient (4%)</td>
</tr>
<tr>
<td>MVR+ AF ablation</td>
<td>One patient (4%)</td>
</tr>
<tr>
<td>Atrial fibrillation (%)</td>
<td>Five patients (20%)</td>
</tr>
<tr>
<td>QRS duration &gt; 0.12 s (%)</td>
<td>One patient (4%)</td>
</tr>
<tr>
<td>Mean LV ejection fraction (±SD)</td>
<td>33.44 ± 10.04%</td>
</tr>
</tbody>
</table>
3. Results

Table 1 demonstrates the pre-operative patient demographics and patient operative details. Five of the patient group were in chronic AF and one patient had a prolonged QRS duration. All procedures were performed with cardio-pulmonary bypass, and moderate hypothermia. Combined antegrade and retrograde cold blood cardioplegia was used for combined CABG and valve procedures, while the remainder had antegrade cold blood cardioplegia. Intra-aortic balloon counterpulsation was required in four patients.

Comparison of the haemodynamic effects of LV relative to RV pacing modes is demonstrated in Table 2. LVP pacing resulted in a significant increase in CI, relative to control (RV pacing) in the overall patient group and in the SR patients. The increase in cardiac index with LVP in the AF patients did not prove significant. Figs. 1 and 2 illustrate the effects of LV pacing upon cardiac indices in all patients and the non-AF sub-group, relative to RV pacing (control). LVA pacing resulted in an insignificant increase in cardiac index in the all patient groups.

Left ventricular work index (LVWi) was significantly increased by both the LVA and LVP pacing modes, relative to controls (RV pacing) in the overall patient group and the non-AF sub-group. In the AF patients, LVWi was not significantly altered by LVA or LVP pacing modes relative to RV pacing.

In the overall study group of 25 patients, both the LVA and the LVP pacing modes significantly increased mean arterial pressure (MAP). Within the sub-group of SR patients, only the LVP pacing mode resulted in a significant increase in MAP (see Table 2). Mean arterial pressure in the AF sub-group was not significantly increased by either LV pacing mode relative to control.

Sample electrocardiographs of one study patient undergoing dual chamber pacing with RV, LVA and LVP pacing modes are demonstrated in Figs. 3 and 4, respectively. This patient had a normal QRS duration pre-operatively and demonstrated complete heart block post AVR and CABG, prior to separation from CPB, necessitating epicardial pacing. LVP and LVA pacing result in shortening of the QRS complex relative to RV pacing.

Epicardial pacing wires were removed in standard fashion prior to discharge. No complications arose from pacing wire implantation or post-operative removal.

Fig. 1. The effect of left ventricular pacing upon cardiac index compared to right ventricular pacing in all patients studied. LVA, LV anterior pacing; LVP, LV posterior pacing; RV, RV pacing/control; pacmode, pacing mode; cindex, cardiac index (l/min per m²).

Fig. 2. Sample electrocardiograph of a study patient undergoing RV pacing mode (dual chamber) post AVR and CABG.
This small study demonstrates that left ventricular pacing, with active lead placement on the postero-lateral LV wall improves CI in patients with LV dysfunction requiring epicardial pacing post cardiac surgery. Improvement in other haemodynamic parameters was also demonstrated. There were no complications with LV pacing in this study.

The beneficial haemodynamic effects of LV pacing, in particular, pacing from the LV posterior wall, were demonstrated in the overall study group and the SR patient subgroup, but not in the small group of patients with AF.

It has been previously proposed that the hemodynamic benefit afforded by the use of biventricular pacing results from LV pacing and resynchronisation of the delayed activation of the LV [2,8]. Little data exist from cardiac surgical patients undergoing LV or biventricular pacing [9,10]. This study demonstrates that pacing from the posterior LV wall gives greater benefit than from the LV anterior wall, compared with the RV. This position is similar to that achieved by transvenous placement of a pacing lead in the postero-lateral branch of the coronary sinus. Animal studies of endocardial pacing suggest that this site leads to earlier activation of the papillary muscle, possibly reducing mitral regurgitation, and increasing stroke volume [13,14].

There were no complications from either LV pacing wire implantation or removal in this study. The only variance from normal practice is that the LV wires must be placed prior to discontinuation of CPB and prior to valve or annuloplasty ring implantation in patients undergoing mitral procedures.

This study does not aim to demonstrate the role of CRT in cardiac surgery patients, but compares LV pacing to RV pacing post-operatively. In summary, this prospective clinical trial of LV anterior and LV posterior pacing compared with RV pacing in 25 patients has demonstrated that LVP pacing leads to improvement in cardiac indices early after cardiac surgery. LV pacing is easy to apply and may improve early post-operative haemodynamic performance in patients with LV dysfunction (regardless of QRS width), in comparison to RV pacing.

5. Limitations of this study

This study was a small pilot study, and comprised patients with heterogenous cardiac pathology. It was not blind, for technical reasons.

References


Fig. 3. Sample electrocardiograph of previous study patient undergoing LVA pacing mode (dual chamber) post AVR and CABG.

Fig. 4. Sample electrocardiograph of previous study patient undergoing LVP pacing mode (dual chamber) post AVR and CABG.