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Biventricular Pacing in the Early Postoperative Period After Cardiac Surgery

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Summary

Cardiac resynchronization therapy is not commonly used in the early postoperative period in patients undergoing cardiac surgery who have left ventricular (LV) dysfunction and a history of heart failure. We performed a prospective randomized clinical trial to compare atrial synchronous right ventricular (DDD RV) and biventricular (DDD BIV) pacing within 72 hours after cardiac surgery in patients with an EF ≤35 %, a QRS interval longer than 120 msec and who had LV dyssynchrony detected by real-time three-dimensional echocardiography (RT3DE). Epicardial pacing was provided by a modified Medtronic INSYNC III pacemaker. An LV epicardial pacing lead was implanted on the latest activated segment of the LV based on RT3DE. The study included 18 patients with ischemic heart disease, with or without valvular heart disease (14 men, 4 women, average age 71 years). Patients undergoing DDD BIV pacing had a statistically significant greater CO and CI (CO 6.7±1.8 l/min, CI 3.4±0.7 l/min/m²) than patients undergoing DDD RV pacing (CO 5.5±1.4 l/min, CI 2.8±0.7 l/min/m²), p<0.001. DDD BIV pacing in the early postoperative period after cardiac surgery corrects LV dyssynchrony and has better hemodynamic results than DDD RV pacing.

Key words

Cardiac resynchronization therapy • Cardiac surgery • RT3DE echocardiography • Heart failure • Hemodynamics

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Introduction

The postoperative period in patients with left ventricular (LV) dysfunction having a LV ejection fraction (EF) ≤35 % is prolonged, with a need for extended inotropic support therapy, prolonged mechanical ventilation or stay in the intensive care unit (Nalysnyk *et al.* 2003). Standard postoperative care at the present time involves atrial synchronous right ventricular (DDD RV) pacing in the case of bradycardia or conduction disturbances. Although it is well known that RV pacing may induce ECG signs of left bundle branch block (LBBB) and LV mechanical dyssynchrony, cardiac resynchronization therapy (CRT) is not routinely used in this high risk group of patients immediately after surgery. The objective of our study was to compare the hemodynamic effect of echocardiographically optimized DDD RV pacing to DDD biventricular (BIV) pacing in patients with LV dysfunction who had mechanical dyssynchrony in the early postoperative period after cardiac surgery. Real-time three-dimensional echocardiography (RT3DE) was used preoperatively as a new approach for detecting LV mechanical dysynchrony and the latest activated segment of the LV for targeted LV epicardial lead placement.

Methods

Our prospective randomized study included patients with sinus rhythm preoperatively a New York

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Heart Association (NYHA) functional class II-IV despite optimal pharmacologic therapy, a history of heart failure due to ischemic cardiomyopathy with severe LV dysfunction, an EF ≤35 %, a QRS longer than 120 msec with preoperatively detected LV dyssynchrony by RT3DE. The patients were then scheduled for myocardial revascularization without LV myocardial resection (aneurysmectomy) and randomized to undergo DDD RV or DDD BIV pacing in the first 72 hours after cardiac surgery. Randomization was carried out after an informed consent form had been signed.

Echocardiography

Two-dimensional (2D) echocardiography measurements were performed according to the guidelines of the American Society of Echocardiography (Lang *et al.* 2005). To measure the mitral inflow velocity, the sample volume of the pulsed Doppler was placed at the mitral valve tips in the apical four-chamber view. The LV outflow velocity was measured from the apical long axis view with the sample volume of the pulsed Doppler just below the aortic annulus.

We used RT3DE to detect LV dyssynchrony before surgery. Acquisitions were made on the Philips iE33 echocardiography machine (iE33 Philips, Andover, MA) using an X3-1 matrix-array transducer. Seven consecutive heart cycles and a constant RR interval were used to create a full-volume acquisition of the LV from the apical window. We used Philips 3DQADV, QLAB, Version 4.2 software that enables semi-automatic endocardial border detection and shows global time to minimum systolic LV volume curves during the cardiac cycle. In this manner we calculated LV volumes (end-systolic volume – LVESV, end-diastolic volume – LVEDV) and LVEF. For evaluating mechanical dyssynchrony we used the 16 segment LV model described by the American Society of Echocardiography (Lang *et al.* 2005). The LV systolic dyssynchrony index (SDI) was calculated as the standard deviation of the time to minimal systolic volume for all 16 segments (Tmsv 16-SD), expressed as a percentage of the RR interval, thus eliminating the effects of heart rate variability (Park *et al.* 2007, Marsan *et al*. 2008). We used a cut-off value of SDI ≥6 % to define LV mechanical dyssynchrony. The latest activated segment of the LV was established with "timing bull's eye parametric imaging" using 3DQ-Advanced QLAB software, Version 4.2, Philips, the Netherlands. The global Tmsv 16-SD as a timing reference was coded in green, early contracting segments were coded in blue, and the latest contracting segments were coded in red/yellow, as described by Soliman *et al.* (2009).

Surgical management

The cardiopulmonary bypass (CPB) circuit was primed with 1000 ml of Ringer's solution and 250 ml of 20 % mannitol. A nonpulsatile flow of 2.4 l/min/m² was established using a membrane oxygenator D703 (Dideco, Italy). Myocardial protection was obtained using cold blood cardioplegic solution. The patients were cooled to 33 °C and perfusion pressure was maintained in the range of 40 mm Hg to 70 mm Hg. The postoperative intensive care was standardized and extubation was performed in hemodynamically stable patients after a period of gradual weaning from mechanical ventilatory support.

Cardiac pacing therapy

Pacing epicardial leads were placed at the end of the operation before sternal closure. Targeted DDD BIV pacing using the Medtronic bipolar lead system (bipolar coaxial 6495, Medtronic Inc, Minneapolis, MN, USA) was performed by placing an epicardial LV electrode on the latest activated segment of the LV based on RT3DE. Other leads were placed on the RV approximately 1-2 cm paraseptally in the lower third of the exposed anterior wall (not on the apex) and on the exposed wall of the right atrium (RA) below the confluence of the superior vena cava (the location of the SA node). The electrode impedance, sensing and pacing thresholds were measured during surgery – a satisfactory threshold was ≤3V/0.5 ms. Correct lead placement was documented during surgery by transesophageal echocardiography and after surgery by chest X-ray. In the early postoperative period, the patients underwent optimization of pacing under echocardiography control (Vivid i GE echocardiography). The atrioventricular delay (AVD) was optimized by measuring the velocity time integral (VTI) of the transmitral flow. Optimum AVD was defined as the AVD resulting in the highest VTI when the A wave of transmitral flow is not truncated. When optimizing the interventricular delay (VVD) we measured the maximal VTI in the LV outflow tract. The pacing rate was 90 bpm. Pacing was provided by a modified Medtronic INSYNC III pacemaker and pacemaker programming was done by a Medtronic programmer.

Hemodynamic measurements

Invasive measurements at the individual pacing modes were performed using a Swan-Ganz 7.5 F/110 cm thermodilution catheter (Edwards Lifesciences LLC Irwine CA). These measurements included mean pulmonary artery pressure (MPAP), cardiac output (CO), cardiac index (CI), pulmonary vascular resistance index (PVRI), systemic vascular resistance index (SVRI), left ventricular stroke work index (LVSWI) and right ventricular stroke work index (RVSWI). The mean arterial pressure (MAP) was measured using a 20G/80 mm radial artery catheter (Arteriofix art.-Kath.-Set- B. Braun Melsugen AG). Measurements were performed immediately after surgery upon arrival in the ICU at the initial pacing mode that was assigned to each patient preoperatively (DDD RV or DDD BIV). Then after a 20 minute washout period the pacing mode was changed (DDD RV to DDD BIV or DDD BIV to DDD RV) and the measurements were repeated. The patients were then returned to the original pacing mode to which they were randomized. A similar series of measurements were performed at 24, 48 and 72 hours after surgery. A comparison between the hemodynamic effect of RV and BIV pacing could therefore be made for each patient. Intravenous drug infusions and inotrope doses were not changed during the measurements. Other patient postoperative therapy was carried out in a standard way, as established for cardiac surgery patients. The inotropic therapy used postoperatively in our study included milrinone (Corotrop; Sanofi-Synthelabo, France) and dobutamine (Dobutamin Lachema; Pliva-Lachema, Czech Republic). Noradrenaline (Noradrenalin; Zentiva, Czech Republic) was administered only when necessary to maintain a target MAP of 70 mm Hg or higher. In the case of atrial fibrillation, the measurements were carried out after conversion to a sinus rhythm using amiodarone or electric cardioversion.

Statistical analysis

The parameters were expressed as mean values ± standard deviation or frequencies. A paired t-test was used for comparison of the two pacing modes (DDD RV and DDD BIV). All tests were two sided with $p<0.05$ considered statistically significant. The statistical analyses were performed using Microsoft Excel and BMDP Statistical Software.

Results

The clinical and echocardiographic characteristics of the study group are described in Table 1. The average age of our patients was 71±9 years, and the majority were men (77.8 % patients). All patients had echocardiographically proven LV enlargement and an average LVEF 26±4 %. Almost one half had severe mitral valve insufficiency (44.4 % patients). All patients in our study had preoperative LV dyssynchrony (SDI ≥6 %) as measured by RT3DE (Fig. 1).

The surgery that was performed (Table 2), included coronary artery bypass grafting with or without a valve procedure. An aortoplasty was also performed in two patients to dilate the aortic root. Epicardial electrodes were placed on the latest activated segment of the LV at the end of surgery based on preoperative RT3DE (Fig. 2). The implantation of epicardial pacing leads did not significantly extend the duration of the surgery.

Table 1. Clinical characteristics and preoperative echocardiographic parameters of the study population (n=18).

Age (years)	71 ± 9
Gender	14 men, 4 women
BMI (kg/m²)	27.8 ± 5
Ischemic heart disease (pts)	18
PFO (pts)	1
Past medical history of hypertension (pts)	16
Hyperlipoproteinemia (pts)	12
Diabetes mellitus (pts)	6
LVEDD (mm)	65 ± 5
LVESD (mm)	50 ± 9
LVEDV (ml)	180 ± 50
LVESV (ml)	134 ± 42
LVEF (%)	25 ± 4
LA PLAX (mm)	47 ± 5
LA A4C (mm)	62 ± 8
Severe mitral valve insufficiency (pts)	8
Severe aortic valve insufficiency (pts)	3
Severe tricuspid valve insufficiency (pts)	2
SDI (%)	≥ 6

Data is presented as mean ± S.D. or number (n). Pts = patients. LVEDD = left ventricular end-diastolic diameter, LVESD = left ventricular end-systolic diameter, LVEDV = left ventricular end-distolic volume, LVESV = left ventricular end-systolic volume, LVEF = left ventricular ejection fraction, LS PLAX= left atrium parasternal long axis diameter, LS A4C = left atrium apical four chamber diameter, SDI = systolic dyssynchrony index measured by RT3DE.

Table 2. Performed cardiothoracic surgery (n=18).

CABG – number of patients/average number of grafts in patients	18/3.5
MVP (pts)	4
MVR (pts)	4
AVR (pts)	3
TVP (pts	2
Aortoplasty (pts)	2
Aortic cross-clamp time (min, mean ± S.D.)	62 ± 32
Cardiopulmonary bypass time (min, mean ± S.D.)	112 ± 34

Data is presented as mean ± S.D. or number (n). Pts = patients. CABG = coronary artery bypass grafting, MVP = mitral valve valvuloplasty, MVR= mitral valve replacement, AVR = aortic valve replacement, TVP = tricuspid valve valvuloplasty.

The most frequent LV epicardial electrode position was on the mid anterolateral segment in 7 patients. Other LV pacing lead postions were basal anterolateral in 4 patients, basal inferolateral in 4 patients and mid inferolateral in 3 patients.

The optimal pacing AVD and VVD were established for each patient before recording hemodynamic measurements, as described in methods. The mean optimal paced AVD was 150-170 ms, the mean optimal VVD was 15-20 ms for LV pre-activation (61 % of patients) and 12-15 ms for RV pre-activation (39 % of patients).

The inotropic support therapy was not changed during the hemodynamic measurements. 13 out of 18 patients received dobutamine (up to 5.0 µg/kg/min) and 6 out of 18 patients received milrinone (0.2-0.3 µg/kg/min). Noradrenaline was administered to 3 out of 18 patients at a mean dose of 0.06 µg/kg/min.

Table 3. Hemodynamic parameters during RV and BIV pacing (n=18).

	RV pacing	**BIV pacing**	**p value**
MAP (mm Hg)	74 ± 9.4	77.3 ± 10.2	p = 0.068
MPAP (mm Hg)	24.4 ± 5.2	22.6 ± 4.7	$p < 0.05$
CO (l/min)	5.5 ± 1.4	6.7 ± 1.8	$p < 0.001$
CI (l/min/m^2)	2.8 ± 0.7	3.4 ± 0.7	$p < 0.001$
SVRI (dyne·sec·cm^{-5}/m^2)	1830 ± 356	1620 ± 443	p = 0.019
PVRI (dyne·sec·cm^{-5}/m^2)	331 ± 124	303 ± 151	NS
LVSWI (g·m/m^2)	29.3 ± 10.3	34.4 ± 10.1	$p < 0.001$
RVSWI (g·m/m^2)	6.9 ± 2.5	8.4 ± 2.8	$p < 0.001$

The data is presented as mean ± S.D. of 4 measurements performed immediately after surgery and 24, 48 and 72 h after surgery. MAP = mean arterial pressure, MPAP = mean pulmonary artery pressure, CO = cardiac output, CI = cardiac index, PVRI = pulmonary vascular resistance index, SVRI = systemic vascular resistance index, LVSWI = left ventricular stroke work index, RVSWI = right ventricular stroke work index. NS = nonsignificant.

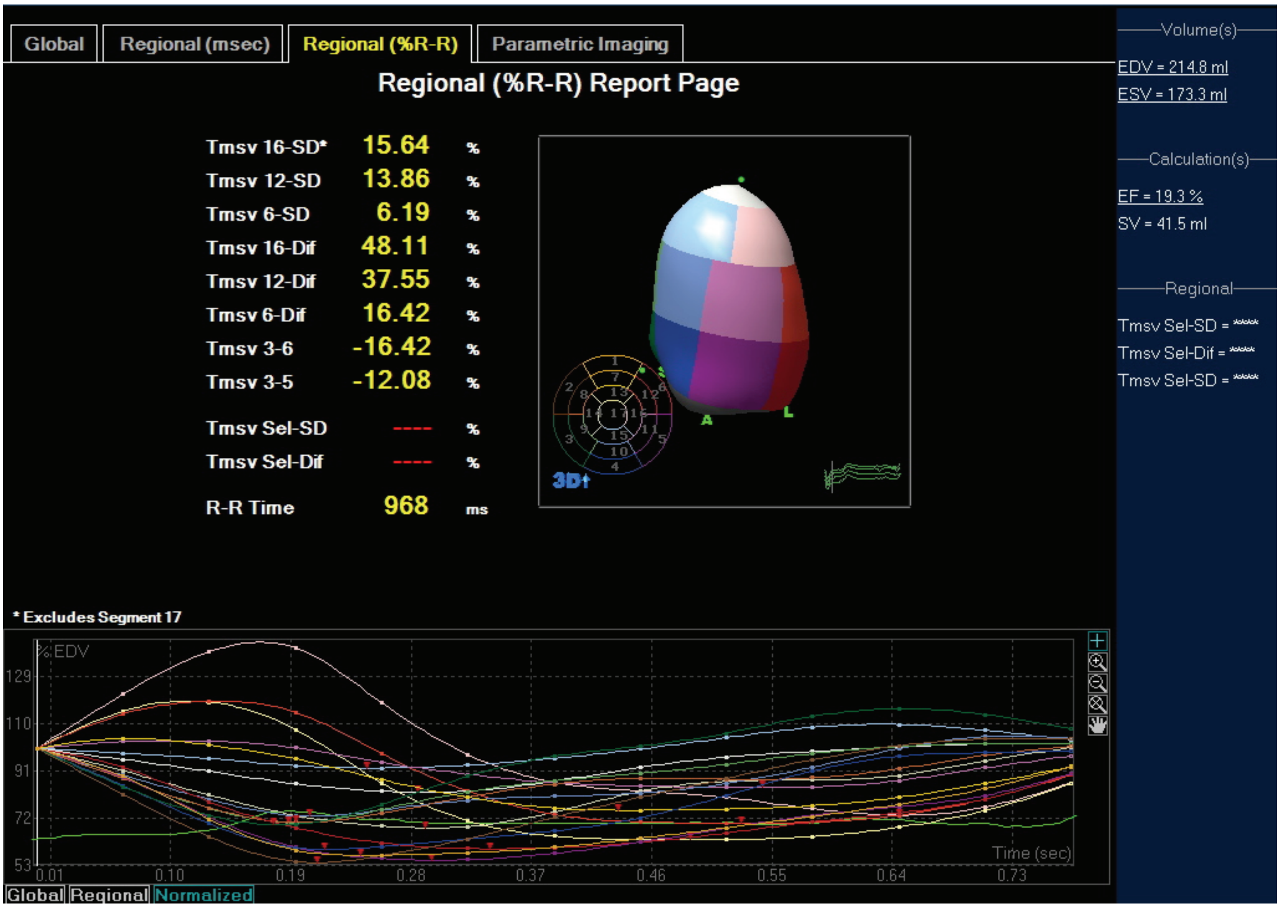
The postoperative hemodynamic parameters during DDD RV and DDD BIV pacing are shown in Table 3. Since hemodynamic parameters did not change significantly during the postoperative period, all calculated hemodynamic values are average values of all measurements performed immediately after surgery, and at 24, 48 and 72 hours postoperatively. During DDD BIV pacing patients had a statistically significant greater CO and CI (CO 6.7±1.8 l/min, CI 3.4±0.7 l/min/m^2) than during DDD RV pacing (CO 5.5±1.4 l/min, CI 2.8±0.7 l/min/m^2), DDD BIV vs. DDD RV $p \leq 0.001$. Patients undergoing DDD BIV pacing also had a statistically significant lower MPAP, higher LVSWI and RVSWI which reflect better LV and RV function, respectively, as well as a statististically significant lower SVRI in comparison to patients undergoing DDD RV pacing. A lower PVRI and a higher MAP were also observed during DDD BIV pacing, although the difference was not statistically significant.

The early postoperative course during the first 72 hours after cardiac surgery was uncomplicated in our group of patients. There were no serious complications related to resynchronization therapy.

The average length of ICU stay was longer for patients randomized to DDD RV pacing (4.0±2.4 days) than for patients randomized to DDD BIV pacing (3.0±1.8 days). In eleven (61 %) of our patients a permanent BIV/ICD pacemaker was implanted for long-term cardiac resynchronization therapy and treatment of ventricular arrythmias. Seven (39 %) of our patients are being followed-up for the potential need of device implantation in the future.

Discussion

The prevalence of chronic heart failure in the general population ranges from 1 to 5 %, and hence there is



Regional (%R-R) Report Page

Tmsv 16-SD* 15.64 %
Tmsv 12-SD 13.86 %
Tmsv 6-SD 6.19 %
Tmsv 16-Dif 48.11 %
Tmsv 12-Dif 37.55 %
Tmsv 6-Dif 16.42 %
Tmsv 3-6 -16.42 %
Tmsv 3-5 -12.08 %

Tmsv Sel-SD ---- %
Tmsv Sel-Dif ---- %

R-R Time 968 ms

* Excludes Segment 17

Volume(s)
EDV = 214.8 ml
ESV = 173.3 ml

Calculation(s)
EF = 19.3 %
SV = 41.5 ml

Regional
Tmsv Sel-SD = ****
Tmsv Sel-Dif = ****
Tmsv Sel-SD = ****

Fig. 1. Example of left ventricular (LV) dyssynchrony analysis (volumetric regional curves of 16 LV segments using RT3DE) before biventricular pacing in a patient with severe mechanical dyssynchrony, systolic dyssynchrony index (SDI) ≥15 %.

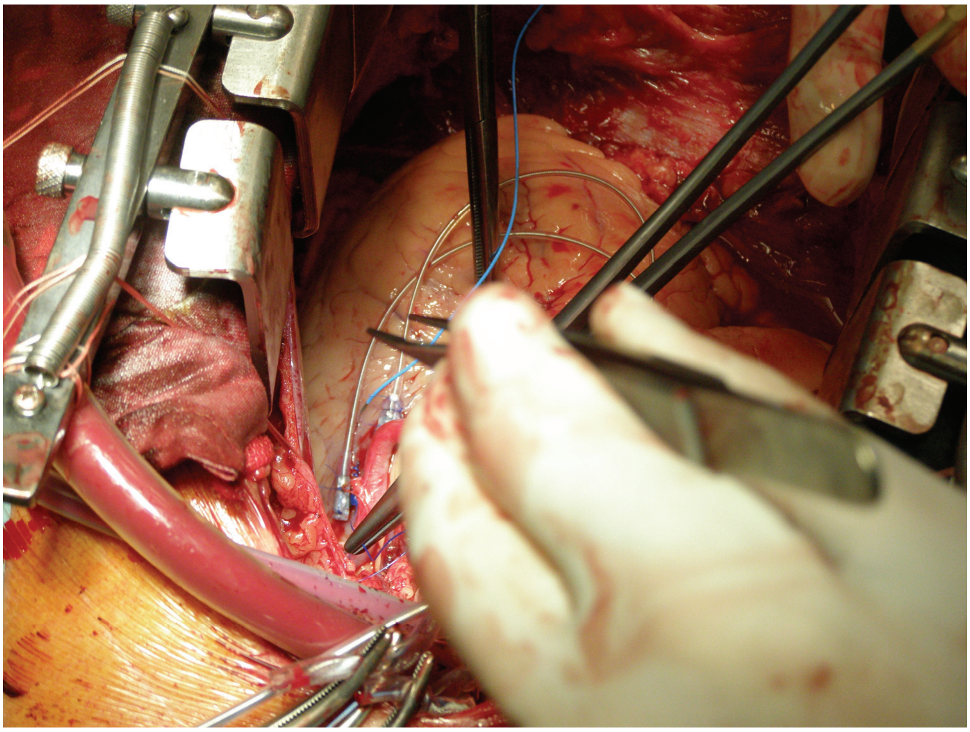


Fig. 2. Peroperative LV epicardial pacing lead placement on the latest activated segment of the LV based on RT3DE.

an increasing proportion of patients presenting for cardiac surgery who have a dilated and dysfunctional LV with an EF ≤35 %, or reduced functional capacity with a history of repeated hospital stay due to heart failure. Several clinical studies have demonstrated the favorable effect of CRT in improving functional classification and stress tolerance in patients with LV dysfunction, chronic heart failure and a New York Heart Association (NYHA) III/IV. As supported by completed trials, CRT also positively influences overall patient morbidity and mortality (The CARE-HF study – Cleland *et al.* 2001, COMPANION trial – Saxon *et al.* 2006). The recently performed MADIT-CRT trial (Moss *et al.* 2009) has shown that CRT combined with an implantable cardioverter defibrillator (ICD) decreased the risk of heart failure events in less symptomatic patients (NYHA class I or II) with ischemic and nonischemic cardiomyopathy, a low EF and wide QRS complex. A 41 % reduction in the risk of heart failure events was observed, primarily in a subgroup of patients with a QRS duration >150 msec. This confirms the importance of CRT even in mildly symptomatic patients who display evidence of mechanical LV dyssynchrony. In this trial CRT was also associated with a significant reduction in LV volumes and improvement in the LVEF. CRT is also associated with LV reverse remodeling and a reduction of mitral regurgitation grade (Senechal *et al.* 2010).

The objective of our study was to evaluate the feasibility and effectiveness of targeted CRT therapy in the early postoperative period after cardiac surgery, to see whether a similar improvement in hemodynamic status would be observed in this high risk group of patients. It is known that the prognosis of cardiac surgery patients deteriorates proportionately with the degree of LV dysfunction and a history of clinically overt heart failure (Nalysnyk *et al.* 2003). The most critical period for these patients is the early postoperative period, which in some cases requires the institution of an intraaortic balloon pump (IABP) or some other mode of mechanical circulatory support, the need for extended administration of catecholamines, prolonged mechanical ventilation, or stay in the postoperative ward (Nalysnyk *et al.* 2003). It is known that obout 9 % of patients after CABG require pacing for atrioventricular block or sinus bradydardia (Bethea *et al.* 2005). In addition to LV dysfunction, the main contributing factor resulting in poor outcome in patients after cardiac surgery may include dyssynchrony of myocardial contraction which reduces the pumping efficacy of the heart. In many cases this is compounded by progressive mitral regurgitation leading to a reduced CO and CI. This negative pathophysiological cycle is often difficult to counter by catecholamine administration or mechanical circulatory support such as IABP. Dyssynchrony may be negatively influenced in the immediate postoperative period by standardly used DDD RV pacing. Liu *et al.* (2008) found that in patients with sick sinus syndrome, acute right ventricular apical pacing (RVA) worsened the myocardial performance index (with RVA pacing 0.42±0.18 vs. without RVA pacing 0.31±14) and lowered the LV ejection fraction as determined by RT3DE (with RVA 54.4±7.7 % vs. without RVA 56.7±7.9 %, p=0.013). In this study, RVA pacing also worsened the parameters of LV dyssynchrony evaluated by RT3DE SDI (with RVA 7.0±2.54 % vs. without RVA 5.36±2.17 %; p=0.003). The standard procedure of implanting only right-sided ventricular epicardial pacing leads results in slow spreading of depolarization through the working myocardium instead of a fast instantaneous spread by the specialized conduction system of the heart. Isolated RV pacing requires myocardial conduction of depolarization through the right ventricle to the left ventricle, which is slower than through the His-Purkinje system. This results in dyssynchrony between the two ventricles (Healy *et al.* 2008).

CRT has not been commonly used in patients after cardiac surgery, and thus there is an ongoing discussion concerning its benefits and its optimal clinical application (Dzemali *et al.* 2006, Muehlschlegel *et al.* 2008, Hanke *et al.* 2009). The proper selection of patients for CRT remains a challenge. It is known that the diagnostic criterion of LV dyssynchrony is not only a wide QRS, but that even patients with a normal QRS interval may have signs of LV dyssynchrony (Achilli *et al.* 2003). Currently, there is an attempt to find the optimal echocardiographic or other method for diagnosing LV dyssynchrony that is reliable and predictive of the response to resynchronization therapy. The multicenter PROSPECT trial (Chung *et al.* 2008) showed great variability in the measurement of a wide range of echocardiographic parameters that were used to diagnose LV dyssynchrony. A very promising method in detecting LV dyssynchrony is RT3DE, which was used in our study. It is possible to establish LV dyssynchrony based on the systolic dyssynchrony index value (SDI). Kleijn *et al.* (2009) reported the optimal cutoff value for SDI by RT3DE to be 6.7 %, which yielded sensitivity of 90 % and specificity of 87 % in predicting the clinical response to CRT, and sensitivity of 88 % and specificity of 70 % in predicting reverse remodeling. Marshan *et al.* (2008) found a cutoff value for SDI ≥5.6 %, which has sensitivity of 88 % and specificity of 86 % in predicting an acute response to CRT. In our group of patients, the cutoff value of SDI of ≥ 6.0 % by RT3DE was connected with improved hemodynamic results during DDD BIV pacing in comparison to DDD RV pacing. In our opinion, this cutoff value of SDI by RT3DE can be used for selecting patients who will benefit from DDD BIV pacing in the early postoperative period after cardiac surgery. However, our results need to be confirmed by larger studies.

There is much controversy regarding the optimal site for pacing lead placement and the best pacing mode in heart failure patients (Butter *et al.* 2001, Dzemali *et al.* 2006, Hanke *et al.* 2009). There is also great individual variability in the optimal site for LV pacing during CRT (Dekker *et al.* 2004). Murphy *et al.* (2006) found that placing the LV electrode at the site of maximal delay is in concordance with LV reverse remodeling and improvement in NYHA class. Merchant *et al.* (2010) in their study compared apical LV lead placement with basal/midventricle lead placement. The event free survival (primary outcome was heart failure hospitalization, cardiac transplantation, or all-cause mortality) was better in the basal/midventricle lead placement group (79 %) than in the apical lead placement group (52 %), hazard ratio [HR] 2.7 (95 % CI: 1.5-5.5, p=0.006). The apical lead placement group also had less improvement in NYHA functional class and less LV reverse remodeling. The explanation for this finding is that pacing in the region of less delayed electrical and mechanical activation cannot adequately correct LV electrical and mechanical dyssynchrony. Ansalone *et al.* (2002) published that in 43 % of patients indicated for CRT the latest activated segment was not in the free lateral or posterolateral wall, which is the common position used during transvenous LV lead placement. In our study we used a new approach where the LV lead was surgically affixed to the site of latest LV activation as determined by RT3DE. This was most frequently in the mid anterolateral segment. A surgical approach for lead placement, in comparison to the transvenous approach, allows accurate placement of the LV pacing lead without the anatomical limitations imposed by cardiac veins. It also allows the surgeon to avoid areas of scarred myocardium and therefore areas of slow conduction (Eberhardt *et al.* 2007).

To optimize AVD and VVD we used conventional Doppler echocardiography, as described by Jansen *et al.* (2006). An optimal AVD and VVD combination is very important in patients with heart failure because it correlates with an improvement in clinical performance status and LV reverse remodeling (Sutton *et al.* 2006). AVD optimization during CRT achieves optimimal LV filling and atrial emptying, and reduces diastolic mitral regurgitation. VVD optimization improves ventricular dyssynchrony leading to a more effective ventricular output.

Hemodynamic monitoring in our study enabled a comparison of two pacing modes in patients after cardiac surgery, DDD BIV pacing and standard DDD RV pacing. Our current results show that targeted DDD BIV pacing in patients with LV dysfunction and heart failure in the early period after cardiac surgery improved hemodynamic parameters (CO, CI) and was significantly better than DDD RV pacing. The feasibility and safety of temporary DDD BIV pacing were demonstrated previously in the study by Eberhard *et al.* (2007), and similar positive results have been reported by Dzemali *et al.* (2008) and Hanke *et al.* (2009). In a recent study by Wang *et al.* (2011), temporary biventricular pacing increased intraoperative CO in patients with LV dysfunction undergoing cardiac surgery. As in our study, the authors reported that AVD and VVD optimization improves this benefit. In our study we used a modified Medtronic INSYNC III pacemaker, but it is possible to use any external pacemaker that permits a DDD BIV pacing mode. Optimized DDD BIV pacing may shorten ICU stay in a high risk group of patients with ischemic heart disease, with or without concomitant valvular heart disease, in the early postoperative period after cardiac surgery in comparison to standardly used DDD RV pacing. Based on accepted guidelines (Dickstein *et al.* 2010), patients who are indicated for cardiothoracic surgery and who fulfill the criteria for CRT (LV dysfunction, EF ≤35 %, QRS ≥120 ms, with signs of LV dyssynchrony) should undergo LV epicardial electrode implantation at the time of surgery with the possibility of long-term DDD BIV or DDD BIV/ICD therapy. Another application of CRT using a surgically implanted epicardial LV lead is in patients where optimal LV lead positioning cannot be achieved *via* the coronary sinus.

Conflict of Interest

There is no conflict of interest.

Acknowledgements

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