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Original article

Pacing of the interventricular septum versus the right ventricular apex: A prospective, randomized study

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ABSTRACT

Background: Left ventricular (LV) function may be impaired by right ventricular (RV) apical pacing. The interventricular septum is an alternative pacing site, but randomized data are limited. Our aim was to compare ejection fraction (EF) resulting from pacing the interventricular septum versus the RV apex.
Methods: RV lead implantation was randomized to the apex or the mid-septum. LVEF and RVEF were determined at baseline and after 1 and 4 years by radionuclide angiography.
Results: We enrolled 59 patients, of whom 28 were randomized to the apical group and 31 to the septal group, with follow-up available in 47 patients at 1 year and 33 patients at 4 years. LVEF in the apical and in the septal groups was $55 \pm 8\%$ vs. $46 \pm 15\%$ ($p = 0.021$) at 1 year and $53 \pm 12\%$ vs. $47 \pm 15\%$ ($p = 0.20$) at 4 years. Echocardiography confirmed a mid-septal lead position in only 54% of patients in the septal group, with an anterior position in the remaining patients. In the septal group, LVEF decreased significantly in patients with an anterior RV lead ($-10.0 \pm 7.7\%$, $p = 0.003$ at 1 year and $-8.0 \pm 9.5\%$, $p = 0.035$ at 4 years), but not in patients who had a mid-septal lead. Left intraventricular dyssynchrony was significantly increased in case of an anterior RV lead. RVEF was not significantly impaired by RV pacing, regardless of RV lead position.
Conclusions: Pacing at the RV septum confers no advantage in terms of ventricular function compared to the apex. Furthermore, inadvertent placement of the RV lead in an anterior position instead of the mid-septum results in reduced LV function.

1. Introduction

Right ventricular (RV) apical pacing has been shown to induce asynchronous ventricular activation [1,2] resulting in detrimental acute [3] and chronic [4] effects on left ventricular (LV) function, as well as in adverse clinical outcome [5]. The right ventricular outflow tract (RVOT) or interventricular septum are safe alternative pacing sites [6–14]. Furthermore, several experimental [15,16] and clinical studies [9,11,17–19] have suggested more physiological LV activation from these sites, resulting in better hemodynamics. However, randomized data concerning the chronic effects of these alternative pacing sites on LV function are lacking, and little is known of the effects of RV pacing on RV systolic function.

The aim of our study was to evaluate the effects on biventricular systolic function by radionuclide angiography, comparing conventional apical pacing to interventricular septal pacing.

2. Methods

2.1. Patient population and study design

We enrolled 59 patients (45 men and 14 women, age 77 ± 7 years) admitted at the University Hospital of Geneva for single (VVI(R)) or dual (DDD(R)) chamber pacemaker (PM) implantation. The inclusion criteria were PM indication for any bradycardia with anticipated RV pacing of more than 50%. Patients with an indication for an implantable cardioverter defibrillator or cardiac resynchronization therapy were excluded. The RV lead position was randomized to either the apex or mid-septum using a random numbers table. Patients were blinded as to their assigned group. The study protocol was approved by the institutional Ethics Committee and all patients provided written informed consent for participating in the study.

2.2. RV lead implantation

All patients received the same model of active-fixation steroid-eluting lead (Medtronic 5076-58, Medtronic Inc., Minneapolis, MN, USA) to avoid differences in handling of leads or complications attributable to specific manufactural design. Leads were positioned on the interventricular septum by using a standard stylet that was manually

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shaped with the barrel of a 10 cc syringe to provide a smooth curve of about 45–60°. The lead was advanced into the pulmonary artery, and then gradually withdrawn while applying counterclockwise torque until it overlay the mid-septal region. Lead position was checked in the left anterior oblique (LAO) 40° view to verify a septal orientation (overlying or adjacent to the spinal column), before deploying the lead helix. Slack was adjusted to achieve good lead stability without an undue rocking motion of the lead tip. Positioning the lead at the right ventricular apex was performed according to usual practice, by using a straight stylet to advance the lead to the apex. In all cases, presence of a current of injury was verified, and lead electrical parameters were measured. Perioperative complications requiring intervention were recorded.

2.3. Follow-up

Device check was performed the day following the PM implant, after 2 months and every 12 months thereafter, in order to verify lead impedance and pacing/sensing thresholds, as well as the percentage of RV pacing. Chest X-rays in posteroanterior and in lateral views were performed on the day of implantation to exclude possible complications. A standard 12-lead electrocardiogram (ECG) was recorded during RV pacing. Radionuclide angiography was performed within 48 h of implantation and after 1 and 4 years. Patients who were randomized to a septal lead underwent transthoracic echocardiography after PM implantation to visualize RV lead position. Standard as well as non-conventional parasternal, apical and subcostal views were used to visualize the lead tip position (lead repositioning was not attempted if the lead was not on the mid-septum). This was not performed in patients with apical leads, as obtaining this target position is straightforward using fluoroscopy.

2.4. Radionuclide angiography

Multigated equilibrium blood pool planar scintigrams were acquired at rest to determine LV ejection fraction (LVEF) and RV ejection fraction (RVEF) and to assess LV dyssynchrony by phase analysis as previously described [20,21]. In order to avoid changes in EF due to heart rate, pacing rate was temporarily programmed to 80 bpm at baseline and at follow-up (in the DDD or VVI modes, as appropriate). Patients' red blood cells were labelled with 1 GBq of technetium-99 m. Planar scintigrams were acquired at 32 frames/cycle (200–250 Kcounts/frame in a 128×128 matrix) using a ADAC-Phillips gamma camera until the number of counts was at least 6×10^6 in the "best-septal" left anterior oblique projection that provided optimal right and left ventricular discrimination. The ECG was monitored continuously for R-wave gating, with elimination of extrasystolic and postextrasystolic cycles. These acquisitions were usually obtained within 10 min for each patient. The RV and LV regions of interest in systole and diastole were drawn by a single investigator (E.F.), who was blinded to the results of RV lead randomization, and EF was computed using the formula: EF = (EDC − ESC)/EDC, where EDC = end-diastolic counts and ESC = end-systolic counts. LVEF and RVEF measurements were repeated by the same investigator to assess intra-operator reproducibility in a subset of 18 and 11 randomly-selected patients respectively. The images acquired for measuring LVEF were digitally processed to display the "phase" of each pixel overlying the ECG-gated equilibrium blood pool, as previously described [22,23]. The computer assigned a phase angle (between 0 and 360°) to each pixel of the image. A phase histogram was thus constructed, corresponding to the sequence of ventricular contraction during the cardiac cycle. The LV was analyzed separately, with calculation of the mean and standard deviation (SD) of the phase histogram. Intraventricular dyssynchrony was calculated by measuring the SD of the phase. Phase data were processed using locally-developed customized software (Hermes Medical Solutions, Stockholm, Sweden). Phase angles were converted from angles to milliseconds using the following formula: (phase angle/360) × RR (ms). A single investigator (H.F.), who was blinded to lead position, performed all these measurements.

2.5. Statistical analysis

Assuming a standard deviation of LVEF of 7% in both groups, we calculated a required sample size of 65 patients to have 80% power to show a 5% absolute difference in LVEF between groups. Statistical analyses were performed using SPSS software (SPSS Inc., Chicago, IL, USA). Continuous data showing normal distribution according to the Shapiro–Wilk test and histogram analysis were compared using paired and unpaired Student's t-tests in case of related and unrelated groups, respectively. The Mann–Whitney test was used for comparing groups with skewed data distribution. Fisher's exact test was used for evaluating dichotomous variables. Continuous values are expressed as mean ± SD unless specified otherwise. Intra-observer reproducibility of LVEF and RVEF measurements was analyzed according to the Bland and Altmann method [24]. A p-value of < 0.05 was considered statistically significant.

3. Results

3.1. Patient population and clinical follow-up

Of the 59 enrolled patients, 28 were randomized to the apical group and 31 to the septal group. No significant differences were found between the two groups regarding baseline characteristics (see Table 1). There was one perioperative complication requiring intervention in a patient randomized to the septal group, in whom RV lead repositioning was performed 4 days after PM implant due to threshold rise. A total of 14 patients died during long-term follow-up (7/28 from the apical group and 7/31 from the septal group, $p > 0.99$), and 12 dropped out (including 1 patient upgraded to an ICD in the apical group and 2 patients upgraded to a biventricular PM in the septal group). The cause of death was non-cardiac in 5 of 14 patients and cardiac with end-stage heart failure in 1 patient in the apical group. The cause of death was unknown in the remaining 8 patients. Thus, data were available in 47 patients at 1 year, and 33 patients completed long-term follow-up after a median of 4.4 years [interquartile range 3.3–5.5]. There were no differences in NYHA class between the apical and the septal groups at follow-up (1.3 ± 0.8 and 1.6 ± 0.9 respectively, $p = 0.53$ at 1 year; 1.2 ± 0.4 and 1.4 ± 0.6 respectively, $p = 0.19$ at 4 years). The percentages of RV pacing (recorded at all follow-ups) were not different between groups: median [interquartile range] for the apical group of 99 [72–100] and 99 [75–100] for the septal group, $p = 0.85$.

3.2. Echocardiographic validation of septal position

A transthoracic echocardiogram of sufficient quality for confirmation of RV lead position was available in 26/31 patients in the septal group. A true mid-septal position was observed in 14 patients, whereas an anterior position was found in 12 patients, of whom 10 had their lead in the groove between the septum and the anterior wall and 2 on the anterior free wall (see Fig. 1).

3.3. Reproducibility of radionuclide angiography

Intra-observer reproducibility of LVEF and RVEF measurements was good, with 95% limits of agreement (in absolute terms) of −1.9 to 2.2% for LVEF and −2.2 to 2.4% for RVEF.

3.4. LVEF

The data are shown in Fig. 2A. LVEF in the apical and in the septal groups was $55 \pm 8\%$ vs. $46 \pm 15\%$ ($p = 0.021$) at 1 year and $53 \pm 12\%$ vs. $47 \pm 15\%$ ($p = 0.20$) at 4 years. There was a significant reduction in LVEF at 1 year compared to baseline in the septal group ($-5.9 \pm$

Table 1
Patient characteristics according to the randomized groups. Percentages are shown in brackets.

	Apical group (n = 28)	Septal group (n = 31)	p
Age (years)	76 ± 7	79 ± 6	0.15
Male	22 (79)	23 (74)	0.77
Pacing indication			
AV block	19 (68)	19 (61)	0.79
2nd degree	8	13	
3rd degree	11	6	
Sinus node dysfunction + AV conduction disease	3 (11)	5 (16)	0.61
AF with slow ventricular rate	6 (21)	7 (23)	>0.99
Pacemaker type			
Single chamber	6 (21)	6 (19)	>0.99
Dual chamber	22 (79)	25 (81)	
Underlying heart disease	20 (71)	21 (68)	0.79
Coronary artery disease	7	5	
Previous myocardial infarction	3	6	
Valvular disease	10	11	
Other cardiopathy	4	5	
Coronary artery bypass surgery	7 (25)	3 (10)	0.17
Valvular surgery	2 (7)	2 (6)	>0.99
Percutaneous coronary intervention	3 (11)	6 (19)	0.48
Hypertension	21 (75)	26 (84)	0.52
Diabetes mellitus	8 (29)	7 (23)	0.77
Chronic AF	6 (21)	7 (23)	>0.99
Treatment	19 (68)	26 (84)	0.22
Beta-blockers	5	3	
Ca^{2+}-channel blockers (dihydropyridines)	5	9	
ACE-Is/ARBs	14	22	
Diuretics	8	8	
Antiarrhythmic drugs	3	7	
Intraventricular conduction defects	25 (89)	22 (79)	0.47
LBBB	6	4	
RBBB	13	11	
Nonspecific intraventricular conduction defects	6	7	
LVEF (%)[a]	54 ± 8	52 ± 13	0.65
LVEF ≤ 45%[a]	5 (18)	9 (29)	0.37
RVEF (%)[a]	44 ± 10	44 ± 7	0.90

ACE-Is, angiotensin-converting enzyme inhibitors; AF, atrial fibrillation; ARBs, angiotensin II receptor blockers; AV, atrioventricular; LBBB, left bundle branch block; LVEF, left ventricular ejection fraction; RBBB, right bundle branch block; RV, right ventricular; RVEF, right ventricular ejection fraction.
[a] At baseline radionuclide angiography, during RV pacing.

9.6%, p = 0.005) but not in the apical group (−1.0 ± 7.1%, p = 0.53). At 4-year follow-up, there was a trend in LVEF reduction in the septal group (−3.8 ± 9.7%, p = 0.12), as well as in the apical group (−3.4 ± 9.7%, p = 0.19). We performed a subgroup analysis according to whether baseline LVEF was greater or less than 45% and we found no differences in results compared to the groups as a whole.

3.5. Changes in LVEF according to actual lead position in the septal group

Patients with an RV lead in an anterior position had a significant reduction in LVEF (−10.0 ± 7.7%, p = 0.003 at 1 year and −8.0 ± 9.5%, p = 0.035 at 4 years), whereas those with a mid-septal position had no significant changes (−2.7 ± 10.2%, p = 0.36 at 1 year and −0.6 ± 7.6%, p = 0.84 at 4 years, see Fig. 2B). Finally there were no significant differences in LVEF at baseline and at follow-up between patients with apical lead and those with a lead truly positioned on the mid-septum.

3.6. Electrocardiographic findings

Paced QRS duration was significantly shorter in the septal group compared to the apical group (150 ± 15 ms vs. 158 ± 17 ms, p = 0.039). There was a trend in shorter QRS duration in patients with a mid-septal lead position compared to an anterior position (148 ± 15 ms vs. 153 ± 16 ms, p = 0.28). Paced QRS axis was significantly more leftward in the apical group than in the septal group (−76 ± 14° vs. -31 ± 63°, p < 0.001). A negative QRS complex in lead I was not an accurate marker of true septal RV lead position, being present in only 1/14 patients with a mid-septal lead and in 12 patients with an anterior lead. There were no significant correlations between paced QRS duration and changes in LVEF at 1 year for the entire patient cohort (r = −0.09, p = 0.57) as well as within the groups (apical group: r = −0.26, p = 0.25; septal group: r = −0.10, p = 0.68).

3.7. Left intraventricular dyssynchrony

LV phase analysis showed no significant increase in LV dyssynchrony at follow-up in both groups (see Table 2). However, significant differences were found between patients with an RV lead on the mid-septum and those with an anterior lead. Marked left intraventricular dyssynchrony was observed at baseline as well as at follow-up in the latter subgroup. No significant differences were observed when comparing patients in the apical group to those with a true mid-septal lead.

3.8. RVEF

There were no significant differences in RVEF between the apical and septal groups (46 ± 6% vs 43 ± 5%, p = 0.13 at 1 year and 46 ± 7% vs 47 ± 4%, p = 0.51 at 4 years).

4. Discussion

The main results of our study comparing chronic pacing from the RV apex vs. the interventricular septum can be summarized as follows: 1) LVEF was not better preserved when the interventricular septum was targeted compared to the apex, 2) pacing from an anterior RV site is potentially harmful, with a significant reduction in systolic function, whereas no changes were observed when the mid-septum was successfully attained, 3) RVEF was not affected by pacing in either group and 4) obtaining a true mid-septal lead position (i.e. avoiding inadvertent placement in an anterior site) was technically challenging using conventional techniques, and was achieved in only about half of the cases.

Several studies have shown that RV apical pacing is associated with a reduction in LVEF [3,4,18,19,25]. Our results showing no significant reduction in LVEF in the apical group are therefore surprising. Contrary to previous publications evaluating septal pacing, atrioventricular nodal ablation was not performed in our patients who were therefore not necessarily paced for 100% of the time. Nevertheless, the median percentage of pacing was 99%, and therefore does not account for the differences in results. Small sample size, limited reproducibility of LVEF measurement (e.g. using echocardiography), and different conditions (e.g. pacing at different rates) may have confounded results in some studies. It is also well known that many patients fare well with long-term RV apical pacing and it remains unclear which factors are predictive of an adverse outcome.

Previous studies randomizing RV apical vs. RV septal (or RVOT) pacing [7–12,14,17–19] have been equivocal regarding the chronic repercussions on LVEF (see Table 3). Our data are in agreement with the canine study by Mills et al. [26], in which no significant differences in LV contractility were found between apical and mid-septal RV pacing. Our study suggests that systolic function is significantly reduced when the lead is inadvertently placed in an anterior position instead of the mid-septum. This finding is in agreement with the results of a non-randomized study by Ng et al. [27], that reported worse ventricular dyssynchrony and LVEF when the RV lead was placed in an anteroseptal position (confirmed by echocardiography) than at the apex. Thus, the inconsistent results of studies on septal pacing may be due to variable positioning of the RV lead, which was not properly evaluated in most studies.

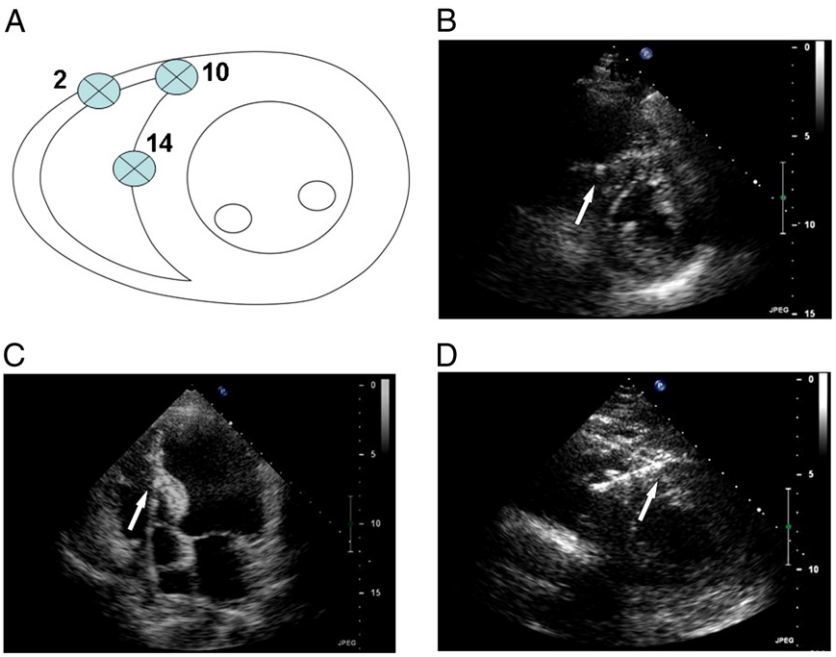

Fig. 1. Validation of RV septal lead position by transthoracic echocardiography. (A) Distribution of RV lead position in septal patients according to echocardiographic validation. RV lead position was sought in all possible echocardiographic views and confirmed by identifying the insertion of the RV lead tip in the myocardium (see arrows). (B) RV lead at mid-septal level in the parasternal short axis view and (C) in the apical four chamber view. (D) RV lead in the groove between the septum and the anterior wall in the parasternal short axis view.

We found that a true mid-septal pacing site avoids the detrimental effects on LVEF resulting from pacing from an anterior site. Other advantages of pacing from the mid-septum rather from an anterior site are reduced risk of cardiac perforation (the septum being thicker than the free wall). In addition, concern has been raised about possible damage to the left anterior descending artery resulting from screwing the lead in an anterior septal position [28]. These points emphasize the importance of proper lead placement on the mid-septum. Special tools such as leads delivered by deflectable or preshaped catheters [29] and stylets with an additional posterior curve [30,31] may be useful to attain the target position. Fluoroscopic landmarks are also of paramount importance, as the present study indicates that the LAO 40° projection is not by itself sufficient to differentiate a mid-septal from an anteroseptal position. We recently published the importance of using right anterior oblique fluoroscopic views with a novel landmark to improve the success rate of mid-septal lead positioning to up to 97% [31]. We also found that chest X-rays were not always useful for confirming true mid-septal lead position (see Fig. 3). ECG markers indicating a septal position (such as a negative QRS complex in lead I) have been proposed [32] but have been shown to be inaccurate [33]. Absence of confirmation of true lead position using methods other than chest X-rays or ECG markers is a major limitation of many studies evaluating septal pacing (see Table 3). Proper validation of final lead position by techniques able to visualize lead tip position (such as echocardiography) should be an integral part of all future papers comparing pacing at different anatomical sites.

There were no differences in clinical outcome or mortality between the groups. In a study randomizing apical vs. RVOT pacing in

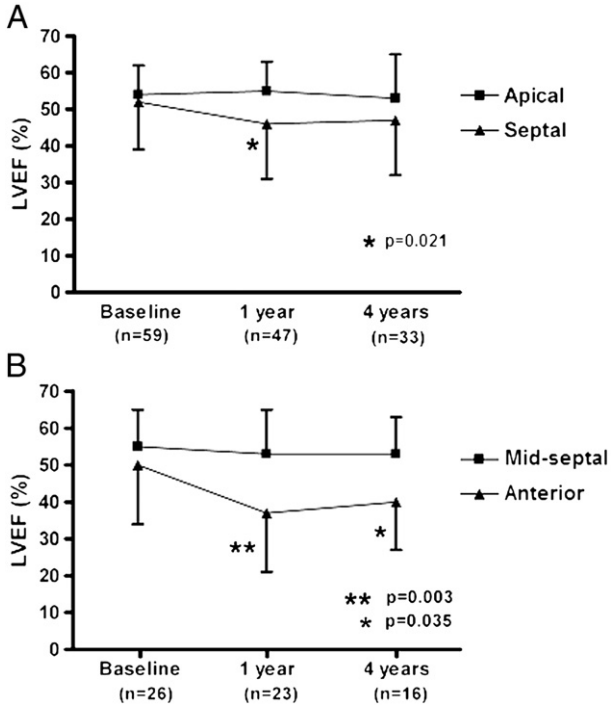

Fig. 2. LVEF at follow-up. (A) Comparison of LVEF according to randomized RV lead position. (B) Changes in LVEF compared to baseline according to echocardiographic validation of RV lead position in the septal group.

Table 2
Left intraventricular dyssynchrony evaluated by radionuclide angiography (SD of the LV phase histogram) during RV pacing at baseline and at follow-up.

	LV phase *SD* (ms)			p
	Baseline	1 year	4 years	
Study group				
Apical	49 ± 18	52 ± 25	50 ± 22	>0.60
Septal	56 ± 25	57 ± 32	64 ± 33	>0.61
P	0.47	0.80	0.12	
Septal subgroup with confirmed lead position				
Mid-septal position	46 ± 16	44 ± 12	49 ± 14	>0.24
Anterior position	73 ± 29	79 ± 39	79 ± 36	>0.68
P	0.006	0.019	0.044	

LV, left ventricular; RV, right ventricular; SD, standard deviation.

Table 3
Randomized studies comparing apical versus septal pacing and chronic effects on LVEF.

Study	Patients (*n*)	Design	Imaging mode	Follow-up (months)	Validation of RV lead position	Outcome
Mera et al. [7]	12	AVN ablation for AF 2 mo X-over RVA vs. RVOT	RNA	2	Fluoroscopy ECG	Resting LVEF better with RVOT No differences in exercise time or exercise LVEF
Victor et al. [8]	16	AVN ablation for AF 3 mo X-over RVA vs. RVOT	RNA	3	Fluoroscopy ECG	No differences in LVEF, VO2 max and CO
Tse et al. [9]	24	AVB, normal LVEF RVA vs. RVOT	RNA	18	Fluoroscopy ECG	Better LVEF and diastolic function with RVOT
Stambler et al. [10]	103	AF, LVEF<40% 3 mo X-over RVA vs. RVOT vs. dual RV pacing	Echo	3	Fluoroscopy ECG Chest X-rays	No differences in LVEF, NYHA, 6-minute walk distance and MR between groups
Victor et al. [11]	28	AVN ablation for AF 3 mo X-over RVA vs. septum	Echo	3	Fluoroscopy ECG	Better LVEF with septal pacing in patients with baseline LVEF<45%
Lewicka-Nowak et al. [18]	27	Standard ventricular pacing indication RVA vs. RVOT	Echo	90	Fluoroscopy ECG Chest X-rays	Better LVEF and diastolic function with RVOT Lower NT-proBNP level at follow-up end in RVOT group
Kypta et al. [12]	98	AVB RVA vs. high or mid-septum	Echo	18	Fluoroscopy ECG	No differences in LVEF, NT-proBNP or exercise
Flevari et al. [17]	26	AVB RVA vs. lower septum	Echo	12	Fluoroscopy ECG Echo	Increase in LVEF with septal pacing
Cano et al. [14]	93	AVB, SSS RVA vs. mid-septum	Echo	12	Fluoroscopy ECG	No differences in LVEF, NT-pro BNP, 6-minute walking test, NYHA functional class Increase in interventricular and in intra-LV dyssynchrony with apical pacing
Leong et al. [19]	58	AVB, SSS RVA vs. septal RVOT	Echo	29	Fluoroscopy ECG	Better LVEF and remodeling with RVOT septal pacing Increase in interventricular and in intra-LV dyssynchrony with apical pacing Greater adverse LA remodeling with apical pacing
Present study	59	Standard ventricular pacing indication RVA vs. mid-septum	RNA	52	Fluoroscopy Echo	No differences in LVEF between groups Reduced LVEF if anterior lead position in the septal group

AF, atrial fibrillation; AVB, atrioventricular block; AVN, atrioventricular node; CO, cardiac output; ECG, electrocardiogram; Echo, echocardiography; LA, left atrial; LVEF, left ventricular ejection fraction; mo, months; MR, mitral regurgitation; NT-pro BNP, N-terminal pro-hormone brain natriuretic peptide; NYHA, New York Heart Association; RNA, radionuclide angiography; RV, right ventricular; RVA, right ventricular apex; RVOT, right ventricular outflow tract; SSS, sick sinus syndrome; VO2 max, peak of oxygen consumption; X-over, crossover.

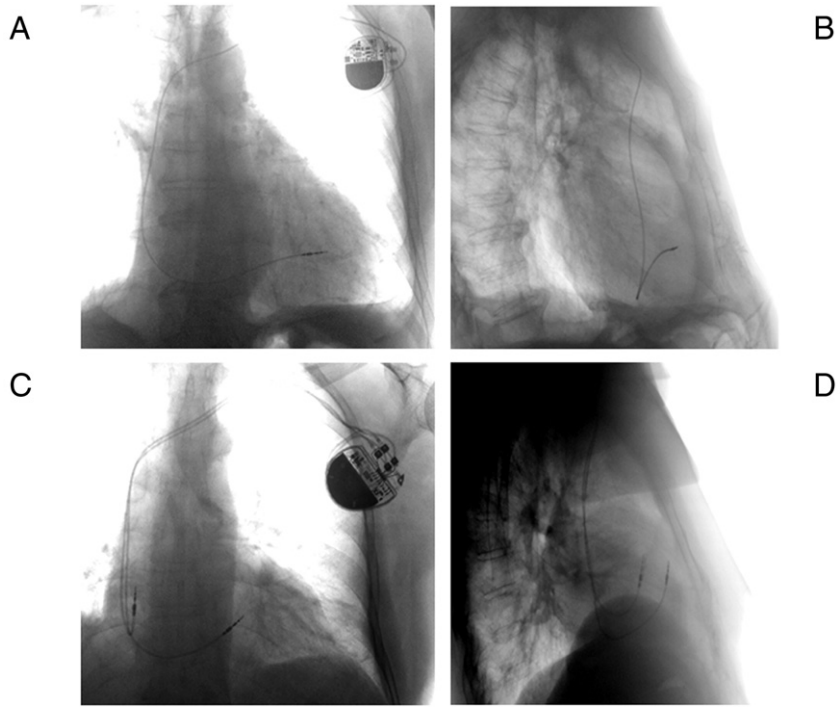

Fig. 3. Chest X-rays in posteroanterior and in lateral views in two patients randomized to the septal group. Echocardiographic validation of RV lead position allowed to confirm a mid-septal position in the patient at the top (A and B), corresponding to the patient of Fig. 1B, whereas an anteroseptal position was found in the patient at the bottom (C and D), corresponding to the patient of Fig. 1D. These cases illustrate how chest X-rays may be unreliable for confirming lead position.

122 patients with preserved LV function, no difference in mortality was observed over a 10-year follow-up [34].

Finally, our study did not indicate any detrimental effect of RV pacing on RVEF, regardless of lead position. Few published data are available regarding effect of pacing on RV function, as this parameter is difficult to evaluate. In an acute study in pediatric patients with normal systolic function, Friedberg et al. [35] found no changes in invasive RV dP/dT_{max} and dP/dT_{neg} measurements resulting from RV pacing. Furthermore, RV function seems not to be impaired by apical pacing in a long-term follow-up, despite induction of electromechanical dyssynchrony, as recently demonstrated by Nunes et al. [36].

4.1. Study limitations

The main limitation of our study is the relatively small final population sample size. This was mainly due to a relatively high dropout and mortality rate (as the patient population was elderly and follow-up long). Also, the advent of algorithms designed to minimize ventricular pacing slowed down recruitment of patients in whom it was anticipated to have >50% ventricular pacing (these devices were favoured to avoid unnecessary and potentially harmful pacing in our patients). For these reasons our study was underpowered to show an advantage of septal over apical pacing, but it is unlikely that increasing the sample size would have changed the results. Finally, echographic validation of septal lead position could not be performed in 5/31(16%) of patients due to poor acoustic windows.

5. Conclusions

Even though our study casts doubt upon the utility of pacing from the RV septum compared to the apex (and even suggests possible harm when the lead is inadvertently placed in an anterior position), our data need to be confirmed by larger studies that are currently underway [29].

Validation of RV lead position by echocardiography is desirable in future studies, as the anatomical pacing site may be variable and is inaccurately predicted by X-rays and the surface ECG. Furthermore new tools and implant techniques should be implemented in order to improve the RV lead positioning at mid-septal site. In the meantime, one may still consider pacing from the RV apex as reasonable practice.

Learning points

- Pacing of the right ventricular apex is known to impair left ventricular function. The interventricular septum has been proposed as an alternative pacing site that may better preserve systolic function. Randomized data are however limited to short-term follow-up without proper validation of lead position.
- Our data indicate that pacing of the ventricular mid-septum does not confer an advantage in terms of left ventricular ejection fraction at up to 4 years follow-up, compared to the right ventricular apex.
- Furthermore, the pacing lead is often inadvertently placed an anterior position when the mid-septum targeted. Sub-group analysis suggests that this pacing site may have a detrimental effect on left ventricular ejection fraction, that is not observed when the mid-septum is correctly attained.

Conflict of interest statement

The authors declare no conflicts of interest.

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