

Assessment of Ventricular Pacing in the Setting of an Institutional Improvement Program: Insights into Physiological Pacing

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Abstract

Background: Excessive ventricular pacing is known to be detrimental. The purpose of this study was to assess ventricular pacing in the setting of an institutional improvement program in order to decrease unnecessary pacing.

Method: This cross-sectional single-center study performed in a university hospital assessed 80 consecutive patients attending for a cardiac electronic device (pacemaker or cardioverter defibrillator) check. Forty percent of ventricular pacing was set as the cutoff level beyond which pacing was considered excessive.

Results: Three patients were excluded. Forty-six (59.7%) patients (group 1) had more than 40% ventricular pacing and 31 (40.3%) patients (group 2) showed ventricular pacing less than 41%. In group 1, corrective action was successful in 27 (58.7%) patients, but 19 (41.3%) continued to have ventricular pacing over 40% and were discussed accordingly. An improvement program was established at the institution in order to decrease unnecessary ventricular pacing.

Conclusion: Unnecessary ventricular pacing was encountered in many of the patients in this study, corrective actions were performed, and an institutional improvement project was set up as a consequence.

Keywords: pacing percentage, physiological pacing, right ventricular pacing, institutional program

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Introduction

Before 1970, ventricular pacing aimed to provide a rate backup and simply had a life-saving purpose. In late 1970s and beginning of the 1980s, the term “physiological pacing” was applied for dual chamber pacers because they preserve the atrioventricular sequence.¹ Until the beginning of the 2000s, the terms “physiological pacemaker” and “physiological pacing” were usually applied simply to designate dual chamber pacers.² Since then, cardiac pacing technology has become increasingly more sophisticated and there has been a trend towards implanting pacemakers not only for life-threatening bradycardia but also to improve hemodynamics and to prevent some supraventricular arrhythmias. Nowadays, the term “physiological pacing” implies preserving and restoring a “normal” electrophysiological activation pattern of the heart,³ ie, up-to-down atrial activation, less interatrial desynchronization, physiological rate-adaptive function, atrioventricular synchronization, intrinsic right ventricular activation with less right ventricular pacing, and avoidance of right ventricular apical pacing.^{3,4} The DAVID (Dual Chamber and VVI Implantable Defibrillator) trial⁵ found that ventricular pacing at more than 40% increased heart failure and mortality rates in a population of patients having an ejection fraction less than 40% and with no conventional indication for a pacemaker. The objective of this study was to assess the percentage of ventricular pacing in the setting of a self-assessment institutional program and to devise a subsequent improvement program for the institution in order to decrease unnecessary ventricular pacing.

Materials and Methods

This was a cross-sectional study in the setting of an institutional university hospital improvement program. Eighty consecutive patients (61% male, mean age 66.01 ± 11.8 years) were enrolled between June and December 2010. The inclusion criterion was consultation for regular device follow-up, whether for a pacemaker or internal defibrillator cardioverter. Patients who had had their devices implanted for less than 30 days and patients with cardiac resynchronization therapy devices were excluded, along with patients for whom ventricular pacing percentage was not assessable with the programmer (old devices or devices with a fully depleted battery). Patient characteristics and

other data were collected from patient records along with data taken during the device follow-up session assigned to the study. All patients signed a written informed consent form to participate in this study. The study protocol was approved by the ethics committee at our institution and conformed to the ethical principles for medical research involving human subjects outlined in the Helsinki Declaration.

Designations and definition

Ventricular pacing was considered excessive if the pacing percentage as assessed during the device follow-up session was more than 40%.⁵ Ventricular pacing dependency was considered present when the underlying rhythm required high ventricular pacing (relative pacing dependency) or permanent ventricular pacing (absolute pacing dependency). Conditions explaining relative ventricular pacing dependency were cases of first degree atrioventricular block with a very long PR interval (>300 msec) requiring ventricular pacing to improve hemodynamics and/or for a better quality of life. Pacemaker syndrome was defined as signs and symptoms induced by right ventricular pacing and most often related to the loss of atrioventricular synchrony.⁶ Ventricular pacing burden was defined as the interactive consequence of two parameters, ie, duration since device implantation and ventricular pacing percentage.

Device check session

Medical history was taken initially with assessment of types of medications, followed by recording of an electrocardiogram for all patients prior to device follow-up. The device follow-up session took place in a dedicated room with three-channel electrocardiographic monitoring. Basic parameters were assessed (basic programmed rate, impedances, battery status, threshold, sensitivity, and underlying rhythm), and the ventricular pacing percentage was then reported.

Corrective actions

When feasible, corrective actions started during the device follow-up session and consisted of device reprogramming in order to decrease unnecessary ventricular pacing as much as possible. Other potentially corrective actions to decrease ventricular pacing percentage consisted of drug therapy adjustment, especially drugs that may affect sinus node automatism



and/or atrioventricular conduction (ie, beta-blockers, calcium channel blockers). We also activated a computer-based program with an alert notice in order to track patients for regular consultation and device follow-up. At the end of this study, a pacer form application was created to be supervised by a committee that must validate the pacing indication for every new patient. This committee consists of three cardiologists, including at least one electrophysiologist. The committee also has the task of recommending which type of device is better to implant (ie, single or dual) and which technique to use (ie, right ventricular septal versus right ventricular apical). Finally, the committee prohibited company technicians from performing device follow-up in the institution unless supervised by an electrophysiologist.

Statistical analysis

SPSS version 16.0 (SPSS Inc., Chicago, IL) was used for the statistical analysis. Continuous variables were expressed as the mean \pm standard deviation and categorical variables were expressed as an absolute number and percentage. Categorical data were compared via the Chi-square test and continuous variable via the Student's *t*-test. Variables found to have significant differences in univariate analysis were evaluated for multicollinearity and then enrolled into multivariable logistic regression analysis (stepwise forward logistic regression). A *P* value <0.05 was considered to be statistically significant.

Results

Of the 80 patients enrolled, 77 patients of mean age 66.01 (range 18–84) years completed the study and three were excluded. Of the 77 studied patients (Table 1), 31 had ischemic cardiomyopathy, 32 had irregular device follow-up, 14 had absolute ventricular pacing dependency and five had relative ventricular pacing dependency, 67 were in sinus rhythm, 45 had dual chamber pacers, and 32 patients had single chamber pacers. Seven patients were found to be left with nominal settings.

Forty-six (59.7%) patients had a ventricular pacing percentage $> 40\%$ (group 1) and 31 (40.3%) had a ventricular pacing percentage $< 41\%$ (group 2). Initial corrective actions when feasible consisted of reprogramming devices in order to decrease ventricular pacing; among the 46 patients in group 1, 27 (58.7%) had their devices reprogrammed and 19 (41.3%) had their devices kept with the same settings due to ventricular pacing dependency, whether absolute or relative.

Thirteen variables were analyzed (Table 1) for their potential impact on ventricular pacing percentage. Irregular device follow-up, dual chamber devices, and ventricular pacing dependency were more prevalent in the subgroup of patients with a ventricular pacing percentage $> 40\%$. Beta-blocker therapy and sinus node dysfunction were more prevalent in the subgroup of patients with a ventricular pacing percentage $< 41\%$. Other parameters did not differ significantly between the two subgroups.

Table 1. Thirteen variables analyzed for their correlation with ventricular pacing percentage.

Patients (n = 77)	VPP $> 40\%$ 59.7% (n = 46)	VPP $< 41\%$ 40.3% (n = 31)	<i>P</i> value
Age (mean \pm SD)	67.15 \pm 12.38	64.23 \pm 10.74	0.293
Male gender	25 (54.3%)	22 (70.9%)	0.077
Irregular device follow-up	24 (52.1%)	8 (25.8%)	0.034*
Time int-S- L6Y	34 (73.9%)	20 (64.5%)	0.596
Dual chamber	32 (69.5%)	13 (41.9%)	0.032*
Relevance of pacing indication	44 (95.6%)	25 (80.6%)	0.149
Electrophysiologist operator	33 (71.7%)	23 (74.1%)	0.535
AV search algoR	6 (13.04%)	6 (19.3%)	0.393
Sinus rhythm	41 (89.1%)	26 (83.8%)	0.942
VPD	14 (30.4%)	0 (0%)	0.001*
Ischemic cardiomyopathy	15 (32.6%)	16 (51.6%)	0.062
Beta-blocker therapy	23 (50%)	22 (70.9%)	0.034*
Sinus node dysfunction	21 (45.6%)	22 (70.9%)	0.014*

Note: **P* < 0.05 , statistically significant.

Abbreviations: Time int-S- L6Y, time interval since implantation less than 6 years; AV search algoR, devices equipped with atrioventricular search algorithm; SD, standard deviation; VPD, ventricular pacing dependency.



Variables with a P value < 0.05 were enrolled into multivariate stepwise logistic regression analysis in order to evaluate their predictive value for ventricular pacing percentage. This analysis showed that only three variables (irregular device follow-up, dual chamber type, and ventricular pacing dependency) were independent predictors of a ventricular pacing percentage $> 40\%$ ($P < 0.05$, Table 2).

New York Heart Association (NYHA) class distribution (Table 3) was reported during device follow-up. The heterogeneity of the population for duration of implantation and ventricular pacing percentage led to different ventricular pacing burdens, and NYHA class is considered a consequence of ventricular pacing burden and not causative of ventricular pacing percentage. For this reason, the influence of NYHA class distribution on ventricular pacing percentage was not included in the statistical analysis.

The study population included 32 single chamber devices and 45 dual chamber devices. Pacing types and their parameters are presented in Table 4. Of the 46 patients with a ventricular pacing percentage $> 40\%$, 27 had device-based correction to reduce their pacing percentage. Among these, eight had single chamber devices and 19 had dual chamber devices; 13 had their atrioventricular delay manually readjusted and six had the automatic atrioventricular search algorithm activated in order to enhance their intrinsic ventricular activation.

Regarding pharmacological intervention, 23 patients in the subgroup with a ventricular pacing percentage $> 40\%$ were taking beta-blockers. Nevertheless, beta-blockers were not found to have a statistically significant impact on ventricular pacing percentage, and no changes were made accordingly. Further, in the subgroup of patients with a ventricular pacing percentage $> 40\%$, there were four patients taking verapamil for hypertension which was replaced with amlodipine. This parameter (calcium channel therapy) in a small

number of patients ($n = 4$) was not considered powerful enough to include in statistical analysis.

Discussion

The rationale for physiological pacing is to restore the normal electrophysiology of the heart and in particular to preserve a normal activation pattern of the ventricles as much as possible. Accordingly, the pacing process should be as “physiological” as possible. Right ventricular pacing is known to be deleterious,^{4,5} with many detrimental consequences, related mainly to atrioventricular and intraventricular dyssynchrony.^{7,8} Therefore, ventricular pacing should be avoided and, in theory, the least possible is desirable. Accordingly, the pacing practice in every institution should aim to decrease unnecessary ventricular pacing. A comprehensive project for controlling parameters that may influence ventricular pacing must be set up for this purpose.

Atrioventricular search algorithms are efficient for enhancing intrinsic ventricular activation. The finding in this study that devices equipped with these algorithms had no significant impact on ventricular pacing percentage is not pertinent. The main explanation is that only 12 patients had devices equipped with these algorithms, and we also found that these algorithms were not activated in all patients, with many of the study patients found to have nominal settings while others had device follow-up performed only by company technicians.

In this study, ventricular pacing dependency was found to be a major determinant of a high ventricular pacing percentage ($>40\%$, $P = 0.001$) and this is a logical finding. Of note, this group of patients are recommended to have their ventricular lead implanted in the right ventricular septum or right ventricular outflow tract.^{3,4} Irregular device follow-up was also found to be a major determinant ($P = 0.034$) of a high ventricular pacing percentage; regular device

Table 2. Correlation of factors in multivariable regression analysis.

Variables	OR	95% CI		P value
		Lower limit	Upper limit	
Irregular follow-up	3.583	1.06	12.11	0.031
Dual chamber type	4.3	1.345	14.043	0.009
VPD	<0.00	0.00		<0.0001

Abbreviations: CI, confidence interval; OR, odds ratio; VPD, ventricular pacing dependency.

**Table 3.** Distribution of different NYHA classes in both subgroups of the study population.

NYHA	VP < 41% (n = 31)	VP > 40% (n = 46)
I	15	23
II	11	11
III	4	9
IV	1	3

Abbreviations: NYHA, New York Heart Association; VP, ventricular pacing.

follow-up is crucial for adapting pacer parameters to the evolving condition of the patient, as well as regular consultation to check for medications that may interfere with atrioventricular conduction. Irregular device follow-up may lead to underdetection of those patients left with nominal settings with a subsequent risk of a high ventricular pacing percentage. This phenomenon was encountered in seven patients in the study population. The influence of company technicians was predominant, and programming done by them was not always adapted to decrease the ventricular pacing percentage, so regular device follow-up should be done by an electrophysiologist to avoid potential misprogramming.

Dual chamber pacers were more prevalent in the subgroup of patients with a ventricular pacing percentage > 40% ($P = 0.032$) and this finding is consistent with the results of the DAVID trial.⁵ This may be explained by potential misprogramming or non-programming of the dual pacers (kept with nominal atrioventricular delay).

The pacing indication is critical for decreasing ventricular pacing, and the best method to avoid ventricular pacing is to avoid pacer implantation if it is not justified. In this study, we found eight patients without any evidence-based indication for pacing.

Table 4. Distribution of device types and parameters in the two subgroups of patients (VP < 41% and VP > 40%).

Total patients (n = 77)	VP < 41% (n = 31)	VP > 40% (n = 46)
Single chamber devices (n = 32) 27 PM (VVIR), 5 ICD	18	14
Dual chamber devices (n = 45) 30 DDD, 8 VDD, 7 ICD	13	32

Abbreviations: ICD, intracardiac device; PM, pacemaker; VP, ventricular pacing.

For this reason, we started to implement the pacer form application in order to adjust pacing indications to guidelines, whereby the pacer form application council has to validate the pacing indication, and recommend the type of device and technique of implantation according to the particular clinical condition of the patient. Finally, we think that company technicians do not necessarily have enough expertise to perform device follow-up and should be supervised by an electrophysiologist.⁹

Corrective action during device follow-up consisted of reprogramming parameters in order to enhance intrinsic ventricular activation. For patients with a VVI(R) pacemaker, whether in sinus rhythm or in atrial fibrillation, we decreased the programmed basic rate in order to enhance intrinsic patient rhythm whenever this was feasible, and we also programmed a night rate “ON” and rate hysteresis “ON” on a case by case basis. For patients in sinus rhythm with a VVI(R) pacer and for whom the above maneuver was not sufficient to enhance intrinsic ventricular activation, a suggestion note was made in the patient records to upgrade to a dual chamber device.

For patients with dual chamber devices, ie, VDD or DDD(R), according to their underlying AVatrioventricular conduction status, we observed intrinsic ventricular activation by reprogramming the atrioventricular delay and/or activating algorithms that enhance intrinsic ventricular activation (when the devices were equipped with these algorithms). For patients with ventricular pacing dependency and for whom ventricular pacing was necessary, we made a suggestion in the patient record to consider septal pacing⁴ or even cardiac resynchronization therapy¹⁰ on a case by case basis, and if the patient’s condition was expected to improve with the suggested upgrading technique. Also, we activated a computer-based program to be implemented in order to track patients and enhance regular device follow-up.

Andersen et al¹¹ showed a lower incidence of atrial fibrillation, less heart failure, and higher survival in patients with sinus node dysfunction treated with atrial pacing (AAI) devices compared with those treated with ventricular (VVI) devices. Of note, all patients had sinus node dysfunction and atrial-based pacing devices were in AAI mode, so the ventricular pacing percentage was absolutely 0% in this subgroup. Accordingly, we hypothesize that these



benefits were mainly related to the absence of right ventricular pacing.

Kerr et al¹² showed no difference in cardiovascular mortality between DDD and VVI groups. The study population included 42% of patients with sinus node dysfunction. In this study, there was no mention of ventricular pacing percentage in the group presumed to be “physiologically” paced (DDD subgroup) and, accordingly, we hypothesize that the absence of a difference regarding cardiovascular outcome could well be related to the detrimental effects of right ventricular pacing in the DDD subgroup.

The UKPACE study¹³ found that the pacing mode (VVI versus DDD) did not affect the incidence of cardiovascular events; ventricular pacing percentage was not mentioned in this study, but we expect that it was significantly high given that the initial indication was high-grade atrioventricular block. Accordingly, we hypothesize that the lack of difference in outcome could well be related to a high ventricular pacing percentage in the DDD group. In MOST (Mode Selection Trial),¹⁴ pacemaker syndrome developed in nearly 20% of the VVIR-paced patients and the authors concluded that avoiding ventricular pacing is helpful to decrease the occurrence of pacemaker syndrome. The ventricular pacing percentage was not mentioned in the above presented studies, probably because state-of-the-art device technology at that time was not developed enough to assess this parameter.

For non-dependent patients, we advocate the use of devices equipped with algorithms to enhance intrinsic right ventricular activation.^{15,16} For patients with ventricular pacing dependency, septal (or outflow tract) pacing is proven to be efficient,⁴ also cardiac resynchronization therapy can be evoked in selected patients with mild to moderate heart failure¹⁰ and has proven to be beneficial and cost-effective. As a result of decreasing ventricular pacing, there is less risk of detrimental effects,^{16–20} including ventricular remodeling and pacing-induced cardiomyopathy.

Conclusion

Right ventricular pacing is deleterious and every effort should be made to decrease it. Many factors must be taken into account in the pacing process in order for pacing to be as physiological as possible.

In this study, 46 (59.7%) patients had a ventricular pacing percentage > 40%, and 27 (35%) patients had their devices reprogrammed in order to decrease ventricular pacing. Irregular device follow-up, ventricular pacing dependency, and dual chamber pacers were found to be independent predictors of a ventricular pacing percentage over 40%. An improvement program regarding the pacing process was set accordingly in our institution.

Limitations

The study was monocentric and cross-sectional, and the study population was limited to 80 patients. In the group of patients with a ventricular pacing percentage > 40%, this percentage was decreased with reprogramming when feasible according to the methods listed above, but no subsequent device follow-up was included in this study to assess whether the ventricular pacing percentage became less than 41% in this group of patients. Due to the limited sample size, study design (cross-sectional and not prospective), and heterogeneity of the patient population, especially regarding hemodynamic status, no analysis to assess the hemodynamic consequences of ventricular pacing percentage was performed. Further, no assessment of potential hemodynamic improvement was performed after decreasing the ventricular pacing percentage. Assessment of ventricular pacing percentage only was set as the main objective, and subsequently the improvement program aimed to decrease the ventricular pacing percentage.

Author Contributions

Conceived and designed the experiments: AK. Analysed the data: AK, SZ, PM. Wrote the first draft of the manuscript: AK, SZ. Contributed to the writing of the manuscript: AK, SZ, PM. Agree with manuscript results and conclusions: AK, SZ, PM. Jointly developed the structure and arguments for the paper: AK, SZ, PM. Made critical revisions and approved final version: AK, SZ, PM. All authors reviewed and approved of the final manuscript: AK SZ, PM.

Disclosures and Ethics

As a requirement of publication author(s) have provided to the publisher signed confirmation of compliance with legal and ethical obligations including but



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