Optimizing the pacing site in the ventricular septum by fluoroscopy and morphology of the paced QRS complex

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Aims. To analyze the paced QRS duration in various septal positions of the right ventricular leads and with different paced QRS vectors. To use the results to assess parameters suggesting the optimal site for right ventricular pacing.

Methods and Results. A total of 609 patients with leads implanted in the right ventricular septum were classified using fluoroscopy in the lateral view (the primary pacing site), and in the anteroposterior view (the secondary pacing site), according to the QRS vector in leads I and III. Significantly shortened paced QRS was found in the primary pacing site with the true septal compared with the anteroseptal site, with the vector being negative or isoelectric in lead I plus positive in lead III. In secondary pacing sites, no significant difference in pacing QRS duration was found between RVOT-HS, RVOT-LS, mid-septum and inferior-septum.

Conclusions. For optimization of the pacing site in the ventricular septum, the following are significant: the primary site based on the lateral view, and the paced QRS vector in leads I and III.

Key words: pacing, paced QRS duration, vector of paced QRS, pacing site optimization

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INTRODUCTION

Permanent pacing from the right ventricular apex (RVA) produces intraventricular dyssynchrony of cardiac contraction¹ posing a risk of left ventricular (LV) dysfunction². The pathophysiological mechanism involves activation of the sympathetic adrenergic nervous and renin-angiotensin systems, impaired myocardial perfusion³, development of remodeling⁴ with progressive worsening of LV function and cardiac failure.

Initial clinical studies compared leads placed in an alternative pacing site in the right ventricular outflow tract (RVOT) with those in the RVA. Most short-term studies found significant differences in hemodynamic parameters in favor of the RVOT (ref.⁵⁻⁷). Some studies, however, reported only insignificant positive hemodynamic changes^{8,9} and also insignificant differences in functional performance in favor of the RVOT (ref.⁹). The randomized ROVA study comparing quality of life in patients with heart failure and atrial fibrillation failed to show differences in quality of life after 3 months of RVOT or RVA (ref.¹⁰). The controversial results may be explained by inhomogeneity of the groups due to difficult fluoroscopic and electrocardiographic characterization of the lead position in the RVOT (ref.^{11,12}). It is likely that due to imprecise RVOT nomenclature and difficult true RVOT septal placement of the lead using standard implantation techniques, the studied groups were not homogeneous, including individuals with RVOT free wall placement.

Some authors prefer the mid-septum, a portion of the

RV septum inferior to the RVOT, to be selected as the pacing site. This position should, given the close proximity of the His-Purkinje system, theoretically produce the lowest level of dyssynchrony of ventricular contraction, since the earliest endocardial signal is recorded in the mid-septum¹³.

In randomized studies, right ventricular nonoutflow septal pacing was compared with RVA pacing. According to LV echocardiographic parameters, the published results documented both the short- and long-term superiority of mid-septal pacing¹⁴⁻¹⁶.

More definitive evidence of the potential benefits of pacing from various precisely defined septal sites over RVA is provided by the results of three randomized prospective multicenter studies – Optimize RV, Protect Pace, RASP – that are currently underway. Each of them compares various septal lead positions with RVA pacing¹⁷. However, the question of the superiority of upper septal or mid-septal pacing remains open.

An alternative to fluoroscopic localization of the optimal position in the RV septum is navigation of the lead using the morphology of the paced QRS complex. The criteria for the final selection of the septal site are the paced QRS vector or duration. The appropriateness of the decision to implant the lead in the RVOT septum based on paced QRS morphology was confirmed by the results of clinical trials^{3,7,18}.

In both the short and medium term, pacing navigated in the RVOT by paced QRS morphology, compared with standard RVA pacing, was more beneficial, as confirmed by the lower incidence of myocardial perfusion defects

Fig. 1. A. Left anterior oblique projection – the distal tip of ventricular lead directed posteriorly indicates the septal position.
B. Anteroposterior projection – the distal tip of ventricular lead in the high septum of RVOT.
C. Lateral projection – the distal tip of ventricular lead directed backwards indicates the true septal position.

Fig. 2. A. Lateral projection – the distal tip of ventricular lead directed perpendicularly indicates the true septal position.
B. The distal tip of ventricular lead directed forwards indicates the antero-septal position.

Fig. 3. A. Anteroposterior projection – the distal tip of ventricular lead in the low septum of RVOT.
B. Anteroposterior projection – the distal tip of ventricular lead in the mid-septum.
C. Lateral projection – the distal tip of ventricular lead in the inferior septum.

and the absence of negative trends in LV ejection fraction³.

Optimization of the pacing site on the RV septum by achieving maximum shortening of the original duration of paced QRS from the RVA led to improved LV function. The positive effect correlated with reduction of the duration of the QRS complex⁷. In contrast, prolonged paced QRS duration in RVA pacing predicted the development of heart failure^{18,19}.

Paced QRS duration reflects homogenization of contraction and is a surrogate marker of dyssynchrony of LV contraction. The relationships between paced QRS complex duration and various sites of septal RV pacing have not yet been studied.

This study aimed at assessing a group of patients with RV septal pacing to find:

- (1) the relationship between septal lead positions and paced QRS complex duration, and
- (2) the relationship between the paced QRS vector and duration of the paced QRS complex.

The results should be beneficial for optimizing the pacing site on the RV septum.

METHODS

Study population and inclusion criteria

Approximately 800 patients with a pacemaker as a primary implant from the Central Military Hospital Prague between 2006 and 2010 were screened for the group. The following inclusion criteria were defined:

- (1) verification of the lead position during implantation in the left anterior oblique (LAO) projection at an angle of 40 degrees, with a distal tip of an active fixation lead being directed posteriorly to the ventricular septum (Fig. 1A), (2) valid documentation containing two fluoroscopic images – anteroposterior (Fig. 1B) and lateral (Fig. 1C) views, and (3) an electrocardiogram of the paced QRS complex in leads I, II and III. The exclusion criterion was recorded LV systolic dysfunction prior to implantation. A total number of 609 patients (337 males, 272 females, mean age at implantation 76.9 ± 8.3) were included. The main indication for the first implantation of single- or dual-chamber pacemakers was symptomatic bradycardia: sick sinus syndrome ($n=243$), second- or third-degree atrioventricular (AV) block ($n=222$), and high-degree AV block in atrial fibrillation ($n=144$). The group was classified according to the septal lead position and paced QRS complex vector. The individual subgroups were compared by the paced QRS complex width.

Fluoroscopic definition of septal pacing sites

For each patient, fluoroscopic documentation was used to classify the RV septal pacing site in two ways. The first classification using a lateral view defined two positions in the RV septum, a true septum position with the lead tip directed backwards (Fig. 1C) or perpendicularly (Fig. 2A), and an anteroseptal position with the lead tip directed forwards (Fig. 2B).

For the second classification, an anteroposterior view

and methods modified by Lieberman were used²⁰. The RV septum was divided into four areas. The RVOT as used in the original classification was subdivided into the high septum (RVOT-HS) (Fig. 1B) and the low septum (RVOT-LS) (Fig. 3A). The septal area under the RVOT is called the extra RVOT septum. This area was subdivided into two identical parallel areas. The upper half of the extra RVOT septum is generally referred to as the mid-septum (MS) (Fig. 3B). The lower half of the extra RVOT septum represents the diaphragmatic portion of the RV septum from the posterior cusp of the tricuspid valve to the septal portion of the RV apex. For this study, it was labeled as the inferior septum (IS) (Fig. 3C).

Determining the paced QRS complex duration

All ECG records were made using an identical ECG device at a speed of 25 mm/s with limb leads I, II and III within 2 months from primary implantation, at a ventricular rate, and atrial rate in dual-chamber pacemakers, of less than 80/min. The paced QRS complex duration was assessed in forced ventricular pacing in the V00 mode at a rate of 90/min. In non-dependent patients with ventricular pacing ($n=597$), the non-paced QRS complex duration was also studied: in the A00 mode at 90/min. in dual-chamber pacing and with suppressed pacing in single-chamber pacing. The paced QRS complex duration was assessed by a single rater from the end of the pacing spike to the latest deflection of the QRS complex in any limb lead I, II or III. The non-paced QRS complex duration was measured from the earliest to the latest deflection in all of the leads.

Defining the paced QRS complex vector

Assessment of the paced QRS complex vector was simplified to determine the R/S voltage ratio in leads I and III. Three categories were defined: positive, isoelectric and negative, with identical criteria for both leads. The interval of the isoelectric vector was widened for this study. As long as the dominant deflection was not more than twice as much as the reverse deflection, the vector was considered isoelectric. A positive vector was defined as $R-S > \frac{1}{2} R$. An isoelectric vector was defined as $R-S \leq \frac{1}{2} R$ or $S-R \leq \frac{1}{2} S$. A negative vector was defined as $S-R > \frac{1}{2} S$. The S wave voltage was calculated in positive values. Based on the resulting vectors in leads I and III, the group was classified into three subgroups: (1) negative or isoelectric in lead I plus positive in lead III, (2) isoelectric or negative in lead III, and (3) positive in lead I and positive in lead III.

Statistical analysis

Standard descriptive statistics were used for the analysis; continuous parameters of QRS duration and the difference between paced QRS and non-paced QRS duration were described by means and standard deviation, while occurrence of categorical parameters (gender, pacing site) were described by count and percentages.

Differences between parameters of QRS duration and the difference between paced and non-paced QRS duration according to several factors and their combination,

Table 1. Basic characteristics of patients.

	N = 609	age
The first position of lead		
Septal	463 (76.0%)	76.7±8.4
Anteroseptal	146 (24.0%)	77.7±8.2
Gender		
Male	337 (55.3%)	76.1±8.4
Female	272 (44.7%)	78.1±8.2
The second position of lead		
RVOT-HS	125 (20.5%)	76.6±8.4
RVOT-LS	219 (24.2%)	76.6±8.5
MS	228 (37.4%)	76.7±8.3
IS	37 (6.1%)	81.9±6.1
Aggregation of the second position of lead		
RVOT-septum	344 (56.5%)	76.6±8.4
Extra RVOT-septum	265 (43.5%)	77.4±8.2
Groups according paced QRS vector in leads I,III		
Negative or isoelectric in lead I and positive in lead III.	275 (45.2%)	76.5±8.7
Isoelectric or negative in lead III.	285 (46.8%)	77.4±7.9
Positive in lead I. and positive in lead III.	49 (8.0%)	77.3±7.6

RVOT-HS = high septum of RVOT, RVOT-LS= low septum of RVOT, MS=mid-septum, IS=inferior septum

were assessed by ANOVA. Homogeneous groups were specified by Tukey's HSD test.

For data analysis, the PASW Statistics 19 for Windows (Release 19.0.1, IBM Corporation 2010) was used $\alpha=0.05$ was considered as the level of statistical significance in all analyses.

RESULTS

Study population and parameters

The baseline characteristics of the 609 patients are given in (Table 1). The statistical analysis results are shown in (Tables 2 to 3). The patients were classified based on the pacing site according to the first and second positions. For individual subgroups, absolute QRS duration and relative QRS duration, i.e. difference between paced QRS duration and native non-paced QRS duration, were calculated. For the studied subgroups, statistically significant differences at the level of significance of 0.05 are stated. Age differences in the subgroups were not significant, with the exception of the smallest subgroup of patients with the pacing site on the inferior septum (6.1%). Age adjustment was not used. Both relative and absolute paced QRS duration was significantly longer in males; the data were adjusted for gender.

Differences in paced QRS duration according to septal pacing site fluoroscopic image

When assessing the first lead position, absolute paced QRS duration was statistically significantly shorter in the septal site subgroup compared with the anteroseptal site. The difference between septal and anteroseptal sites was statistically significant even after adjustment for gender.

In the case of the septal site, the relative QRS complex duration was also shorter but the difference was not statistically significant (Table 2.).

Also statistically insignificant was the difference in absolute duration of paced QRS between subgroups defined according to the secondary pacing site, RVOT-HS, RVOT-LS, MS and IS. Only after RVOT-HS was put together with RVOT-LS and MS with IS to form two subgroups, (septal in the RVOT and septal outside the RVOT), was a statistically significant difference found, with shorter paced QRS in the septal RVOT subgroup. After adjustment for gender, the difference was significant in females but not in males. After adjustment for the first true septal and anteroseptal sites, the power of the difference between RVOT and extra RVOT was lost. The relative paced QRS complex duration did not differ in the various septal sites (Table 2.).

Differences in paced QRS duration according to the paced QRS vector

After the group was classified into the above groups using the paced QRS vector, statistically significant differences in paced QRS duration were found. The shortest duration was in the negative or isoelectric in lead I plus positive in lead III vector subgroup, medium duration in the isoelectric or negative in lead III subgroup, and the longest paced QRS was in the positive in lead I and positive in lead III subgroup. The differences in paced QRS interval according to the vector were statistically significant even after adjustment for the true septal site, with the positive in lead I and positive in lead III subgroup being significantly different from the other two vector subgroups. After adjustment for the anteroseptal site, the difference between the negative or isoelectric in lead I plus

Table 2. Comparison of paced QRS duration and difference between paced and non paced QRS duration according pacing site, paced QRS vector, gender and the second position of electrode.

		Paced QRS duration		Difference between paced and non paced QRS duration	
		N	Mean $\pm$ SD	N	Mean $\pm$ SD
Total		609	14.4 $\pm$ 1.6	597	4.1 $\pm$ 2.7
Pacing site					
	True-septal	463	14.0 $\pm$ 1.5	457	3.7 $\pm$ 2.3
	Anteroseptal	146	15.6 $\pm$ 1.6	140	5.2 $\pm$ 3.3
	<i>P</i> ¹		<0.001 *		<0.001 *
Gender					
	Male	337	14.8 $\pm$ 1.7	331	4.0 $\pm$ 2.8
	Female	272	13.9 $\pm$ 1.5	266	4.2 $\pm$ 2.5
	<i>P</i>		<0.001 *		0.242
Combination of gender and pacing site					
	Male & True-septal	243	14.4 $\pm$ 1.5 ^a	240	3.6 $\pm$ 2.5 ^a
	Female & True-septal	220	13.7 $\pm$ 1.4 ^b	217	3.9 $\pm$ 2.1 ^a
	Male & Anteroseptal	94	15.9 $\pm$ 1.7 ^c	91	5.1 $\pm$ 3.3 ^b
	Female & Anteroseptal	52	14.9 $\pm$ 1.3 ^d	49	5.4 $\pm$ 3.2 ^b
	<i>P</i>		<0.001 *		<0.001 *
Second electrode position					
Aggregated position of lead					
	RVOT-HS, RVOT-LS	344	14.1 $\pm$ 1.5	335	4.1 $\pm$ 2.7
	MS, IS	265	14.8 $\pm$ 1.7	262	4.0 $\pm$ 2.6
	<i>P</i> ¹		<0.001 *		0.643
Combination of positions					
	RVOT-HS, RVOT-LS & True-septal	297	13.9 $\pm$ 1.4 ^b	292	3.9 $\pm$ 2.3 ^a
	MS, IS & True-septal	166	14.3 $\pm$ 1.6 ^b	165	3.5 $\pm$ 2.3 ^a
	RVOT-HS, RVOT-LS & Anteroseptal	47	15.4 $\pm$ 1.7 ^a	43	5.8 $\pm$ 3.9 ^b
	MS, IS & Anteroseptal	99	15.6 $\pm$ 1.6 ^a	97	5.0 $\pm$ 2.9 ^b
	<i>P</i>		<0.001 *		<0.001 *
Combination of position and gender					
	RVOT-HS, RVOT-LS & Male	181	14.6 $\pm$ 1.6 ^{b,c}	177	4.0 $\pm$ 3.0
	MS, IS & Male	156	15.0 $\pm$ 1.8 ^c	154	4.0 $\pm$ 2.6
	RVOT-HS, RVOT-LS & Female	163	13.6 $\pm$ 1.2 ^a	158	4.3 $\pm$ 2.2
	MS, IS & Female	109	14.5 $\pm$ 1.6 ^b	108	4.1 $\pm$ 2.8
	<i>P</i>		<0.001 *		0.727

¹ Statistical significance of ANOVA; * statistically significant² Homogeneous groups were specified by Tukey's HSD test

RVOT-HS = high septum of RVOT, RVOT-LS= low septum of RVOT, MS=mid-septum, IS=inferior septum

positive in lead III subgroup and the positive in lead I and positive in lead III subgroup was statistically significant.

After the QRS vector was adjusted for gender, there were differences in paced QRS duration between all three subgroups in females. In males, however, the statistically significant difference was only between the negative or

isoelectric in lead I plus positive in lead III subgroup and the positive in lead I plus positive in lead III subgroup.

There was a difference in the relative QRS complex duration between two subgroups only, the negative or isoelectric in lead I plus positive in lead III subgroup and the positive in lead I and positive in lead III subgroup. The

Table 3. Comparison of paced QRS duration and difference between paced and non paced QRS duration according combination of paced QRS vector in leads I, III. and pacing site.

	Paced QRS duration		Difference between paced and non paced QRS duration	
	N	Mean $\pm$ SD	N	Mean $\pm$ SD
Paced QRS vector in leads: I, III				
Negative or isoelectric in lead I and positive in lead III	275	13.8 $\pm$ 1.4 ^a	270	3.8 $\pm$ 2.4 ^a
Isoelectric or negative in lead III	285	14.8 $\pm$ 1.7 ^b	280	4.1 $\pm$ 2.7 ^a
Positive in lead I. and positive in lead III.	49	15.7 $\pm$ 1.4 ^c	47	6.0 $\pm$ 3.2 ^b
<i>P</i> ¹		<0.001*		<0.001*
Combination of pacing site and paced QRS vector				
True-septal & negative or isoelectric in lead I and positive in lead III	251	13.7 $\pm$ 1.3 ^a	248	3.7 $\pm$ 2.3 ^a
True-septal & isoelectric or negative in lead III	183	14.3 $\pm$ 1.6 ^{a,b}	180	3.6 $\pm$ 2.4 ^a
True-septal & positive in lead I. and positive in lead III.	29	15.3 $\pm$ 1.1 ^c	29	4.9 $\pm$ 2.2 ^a
Anteroseptal & negative or isoelectric in lead I and positive in lead III	24	14.8 $\pm$ 1.6 ^{b,c}	22	4.7 $\pm$ 3.5 ^a
Anteroseptal & isoelectric or negative in lead III	101	15.6 $\pm$ 1.6 ^{c,d}	99	4.9 $\pm$ 2.9 ^a
Anteroseptal & positive in lead I. and positive in lead III.	21	16.2 $\pm$ 1.5 ^d	19	7.3 $\pm$ 4.0 ^b
<i>P</i>		<0.001*		<0.001*
Combination of gender and paced QRS vector				
Male & negative or isoelectric in lead I and positive in lead III	131	14.3 $\pm$ 1.5 ^b	129	3.5 $\pm$ 2.8 ^a
Male & isoelectric or negative in lead III	168	15.0 $\pm$ 1.8 ^{b,c}	165	4.0 $\pm$ 2.7 ^a
Male & positive in lead I. and positive in lead III.	38	15.8 $\pm$ 1.5 ^c	37	5.6 $\pm$ 3.1 ^b
Female & negative or isoelectric in lead I and positive in lead III	144	13.4 $\pm$ 1.1 ^a	141	4.0 $\pm$ 2.0 ^a
Female & isoelectric or negative in lead III	116	14.5 $\pm$ 1.6 ^b	114	4.2 $\pm$ 2.7 ^a
Female & positive in lead I. and positive in lead III.	12	15.4 $\pm$ 1.1 ^c	11	6.8 $\pm$ 3.9 ^b
<i>P</i>		<0.001*		<0.001*

¹ Statistical significance of ANOVA; * statistically significant² Homogeneous groups were specified by Tukey's HSD test

difference was apparent even after adjustment for gender (Table 3).

DISCUSSION

Selection of the pacing site in the RV septum

The septal position of the pacing lead in the right ventricle is a preferred alternative pacing site given the potential contribution of limiting LV dyssynchrony compared with RVA stimulation. So far, the preferred pacing site in the RV septum has not been agreed upon, with some advocating the septal part of the RVOT and others preferring the mid-septum. The decision of where in the septum the lead should be placed is individual, with the selection being corrected according to the paced QRS complex duration. The inferior septum is generally a less preferred alternative destination, probably due to the close

proximity of the apical position. Similarly, in our group, the pacing site in the inferior septum was only sporadically represented (6.1%). This study comparing various pacing sites in the RV septum according to paced QRS duration, aimed at adding information to the algorithm for selecting the pacing site in the RV septum.

In this study, the first assessed septal pacing sites were two positions according to lateral fluoroscopic image – the true septal and anteroseptal sites. We consider differentiation between these two sites to be of crucial importance given the extent of interventricular dyssynchrony of paced ventricular contraction related to the anatomical course of the His-Purkynje system. Differentiation of the two sites in the group enables filtering of potential adverse effects of anteroseptal pacing. Failure to differentiate anteroseptal and anterolateral pacing from true septal pacing in the RVOT may partly explain the controversial results of studies⁸⁻¹⁰.

The secondary septal pacing sites were areas according to the anteroposterior view based on repeatedly reported fluoroscopic criteria²⁰. Two positions were defined in the RVOT septum, high-septum RVOT and low-septum RVOT, and two positions in the septum outside the RVOT, mid-septum and inferior septum (Fig. 1B, 3A-C).

Justification of paced QRS duration as a parameter of the optimal septal site

The paced QRS complex duration quantifies homogenization of ventricular contraction. With His-bundle pacing, a short paced QRS complex is recorded and interventricular dyssynchrony is not induced²¹. In earlier studies, the QRS duration was used as a criterion for selecting the optimal pacing site in the RV septum, with a confirmed hemodynamic benefit compared with RVA pacing^{3,7,15}. Given this evidence and easy quantification of the parameter, paced QRS duration was selected as the only parameter of the optimal RV pacing site in this study.

Due to several cases of difficult and ambiguous classification of pacing sites according to fluoroscopic criteria, the significance of easily measurable paced QRS morphology with respect to prediction of paced QRS duration was alternatively tested. Based on the paced QRS vector, three subgroups were created, corresponding to the basic pacing sites in the RV septum, the RVOT, extra RVOT and anteroseptal positions.

Differences in paced QRS duration

When assessing the paced QRS complex duration in our group of 609 patients, the initial findings were different gender-related values. These findings were not surprising. In the male population, longer paced as well as native QRS duration are associated with larger heart chambers, in particular the larger end-diastolic size of the left ventricle.

When comparing paced QRS according to pacing sites in the RV septum defined by fluoroscopic criteria, the most significant difference was found between the true septal and anteroseptal subgroups, in favor of the true septal one (Table 2.). The difference was apparent even after adjustment for gender. According to our results, the true septal pacing site is optimal, given limited potential intraventricular dyssynchrony. The true septal position, a surgeon's preferred target for the final destination of the lead, was reached in most patients in our group (76%). Of particular interest are different success rates in reaching the true septal site in and outside the RVOT. Implantation of the lead in the true septum was more frequent in the RVOT area (84%) compared with the mid-septum or inferior septum areas (40%). The difference probably results from more difficult directing of the lead tip backwards in the mid- and inferior septal areas compared with the RVOT.

In patients with the long native QRS complex, the difference between the true septal and anteroseptal sites was not clearly beneficial. With infra-Hisian blocks, the benefit of pacing in the proximity of the bundle of His is probably decreased.

The secondary assessed pacing sites in the RV septum (Table 2) showed no significant differences in paced QRS duration. Division of the septum into 4 areas, RVOT-HS, RVOT-LS, MS and IS, was not significant with respect to paced QRS duration. Therefore, the areas were aggregated into two subgroups, RVOT septum (56.5%) and extra RVOT septum (43.5%). The subgroup of patients with the lead placed in the RVOT septum reached significantly shorter paced QRS duration compared with the extra RVOT septum site. Given the results of our group, the pacing site in the RVOT septum might seem more beneficial. After adjustment for the primary true septal and anteroseptal sites, however, the difference in paced QRS duration was not significant. Thus, the shorter QRS duration in the RVOT septum may be explained by a higher frequency of the septal primary site compared with a higher frequency of the extra RVOT anteroseptal site. The RVOT septal site may only be preferred because of the higher probability of reaching the true septum site.

Classification of the group into three subgroups according to the paced QRS vector in leads I, II and III (Table 3) also provided subgroups with statistically different paced QRS duration. The shortest QRS was noted in the negative or isoelectric in lead I plus positive in lead III vector subgroup, the longest in the positive in lead I and positive in lead III subgroup. After adjustment for the primary true septal and anteroseptal sites, the two different paced QRS morphologies still showed a significant difference in paced QRS duration. This result is surprising given the aforementioned insignificant difference between fluoroscopic positions in the RVOT and outside the RVOT (Table 2).

Priority of the true septal site

According to our results, the true septal site is a significant marker of the optimal pacing site in the RV septum with respect to paced QRS duration. Differentiation of other secondary positions in the high RVOT, low RVOT, mid-septum and inferior septum is not of crucial importance with respect to paced QRS duration. This assumption is also supported by common experience with RVA pacing, with the relatively short QRS complex being observed only in patients with passive leads leaned against the ventricular septum. This is confirmed by a study in which the benefit of optimized septal site correlated with achieved shortening of the paced QRS complex compared with RVA (ref.⁷). If in RVA pacing the original QRS was relatively short, the lead in RVA was probably placed in the septum and hence the positive effect of septal pacing optimization was minimal as compared with RVA.

Secondary optimization of the pacing site using fluoroscopic criteria in the anteroposterior view is not beneficial with respect to paced QRS duration. Selection of the site in the RVOT septum compared with extra RVOT may only be recommended for a higher probability of reaching the true septum. Another criterion for the lateral view for more precise definition of the site may be assessment of the paced QRS vector. The preferred vector is negative or isoelectric in lead I plus positive in lead III. By contrast,

another pacing site should be sought in the case of the positive in lead I and positive in lead III subgroup.

Implications of results

After verification of the septal position by fluoroscopy LAO projection at an angle of 40 degrees, the pacing site may be optimized according to repeated measurements of the paced QRS complex and then the lead may be implanted in the site with the shortest duration. Alternatively, the results of our group suggest that after mandatory verification of the septal site in the LAO, it may be recommended to continue optimizing the pacing site using the fluoroscopic lateral view in order to reach the true septum with directing the lead tip dorsally or vertically. To define the site more precisely or, alternatively, in the case of the non-standard use of the lateral view during implantation, it may be beneficial to assess the paced QRS vectors in leads I and III. By contrast, more detailed differentiation of the pacing site in the septum using the anteroposterior fluoroscopic criteria is only beneficial for assessing the lead stability and with respect to interventricular dyssynchrony, it is probably of no major importance.

CONCLUSIONS

In a total of 609 patients, optimal septal sites were defined based on statistical analysis of paced QRS duration. A significant difference was found between the true septal and anterosseptal sites assessed by the fluoroscopic lateral view. By contrast, different septal sites defined by fluoroscopic criteria in the anteroposterior view showed no significant differences in paced QRS duration. To optimize the pacing site in the septum, assessment of the paced QRS vector is of benefit.

CONFLICT OF INTEREST STATEMENT

Author's conflict of interest disclosure: The authors stated that there are no conflicts of interest regarding the publication of this article.

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