CLINICAL SIGNIFICANCE OF QRS COMPLEX DURING VENTRICULAR PACING

A non-invasive study

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Fifty-seven patients with artificial pacemakers were studied from electrocardiograms (ECGs), vectorcardiograms, echocardiograms, and non-invasive techniques of systolic time intervals. Thirty-nine patients demonstrated a left bundle branch block (LBBB) pattern induced by transvenous right ventricular (RV) pacing, and 9 patients demonstrated a right bundle branch block (RBBB) pattern also induced by transvenous RV pacing. Perforation of the right ventricle or malpositioning of the catheter electrode was not recognized. Eight patients with epicardial left ventricular (LV) pacemakers showed a RBBB pattern and one showed a LBBB pattern. The maximal QRS vector of a RBBB pattern produced by RV pacing was directed leftwards and anteriorly, whereas that of a RBBB pattern produced by LV pacing was oriented rightwards and posteriorly. A rapid initial posterior motion of the left side of the interventricular septum (IVS) during early systole and/or anterior or flat motion of the IVS during the ejection period was almost exclusively indicative of RV pacing, regardless of the ECG wave form. There was one exceptional case in LV pacing, which showed a LBBB pattern with the same septal motion as that in RV pacing. However, the direction of the maximal QRS vector in this case was directed inferiorly, which is in sharp contrast to that in the RV pacing which was directed superiorly. There was no significant differences in systolic time intervals between a LBBB pattern and a RBBB pattern in RV pacing. Based on the hypothesis that the ECG wave form induced by epicardial LV pacing might be equivalent to that in a case of perforated right ventricle, the following conclusions can be drawn from the present study.

- (1) A RBBB pattern in RV pacing could be differentiated from perforation of the right ventricle. The following findings may suggest uncomplicated RV pacing:
 - (a) the left and anterior orientation of the maximal QRS vector, and
 - (b) a rapid initial posterior septal motion during the early systole and/or a paradoxical anterior septal motion during the ejection period.

Key words:

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- (2) A RBBB pattern in uncomplicated RV pacing does not require the repositioning of the catheter electrode.
- (3) A LBBB pattern with inferior orientation of the maximal QRS vector would suggest perforation of the right ventricle.

It is well established that the morphology of the QRS complex during artificial ventricular pacing depends on the site of pacemaker stimulation. While transvenous right ventricular (RV) pacing yields a left bundle branch block (LBBB) pattern, left ventricular (LV) pacing results in a right bundle branch block (RBBB) pattern.¹⁻⁵ Although a RBBB pattern may develop during transvenous pacing if the catheter perforates the right ventricle or stimulates from the coronary venous system,⁴⁻¹⁴ it appears unlikely that RBBB patterns during transvenous pacing are commonly related to such complications.¹⁵ To determine whether or not a RBBB pattern induced by RV pacing is a result of perforation of the right ventricle or an abnormal catheter position is clinically important. The present study was designed to evaluate the morphology of the QRS complexes in patients with artificial pacemakers.

MATERIALS AND METHODS

Fifty-seven consecutive patients with electronic pacemakers were studied from electrocardiograms (ECGs), vectorcardiograms (VCGs), echocardiograms, and non-invasive techniques of systolic time intervals. In this study, 35 patients were men and 22 were women, ranging in age from 20 to 91 years. They were divided into three groups, as follows. Group I comprised of 39 patients with transvenous endocardial RV pacemakers whose ECGs showed the expected LBBB type QRS morphology. Group II consisted of 9 patients with transvenous endocardial RV pacemakers. The ECGs in lead V₁ showed a RBBB pattern in 7 patients and a prominent R wave in 2 patients. Patients with evidence of malpositioning of the pacing catheter within the coronary venous system or the right ventricular outflow tract were excluded from Group II. An examination at autopsy in one patient confirmed a catheter position in the endocardium near the apex of the right ventricle. The etiology of the cardiac disease in Group II was thought to be coronary artery disease in 4 patients, hypertensive heart disease in one, congestive cardiomyopathy in one, postmyocarditis in one and remain-

ed unknown in two (Table I). Group III consisted of 9 patients with epicardial LV pacemakers having a RBBB type QRS morphology in 8 patients and a LBBB type morphology in one. Clinical records, standard 12-lead ECGs, VCGs, echocardiograms and frontal and lateral chest roentgenograms were obtained for all patients. The VCGs were recorded with Frank's orthogonal lead system.¹⁶ The frontal, left sagittal and horizontal planes were displayed with Fukuda VA-3D vectorcardiograph and photographed with a polaroid camera. The VCG loops were interrupted at a rate 400 times per second. Details of the recording system and techniques have been described previously from this department.¹⁷

The echocardiographic studies were undertaken with an Aloka SSD-110, using a 10 mm diameter, 2.25 MHz transducer focussed at 7.5 cm. The echocardiograms were recorded on a Toshiba SSL-51-U strip chart. The patients were examined in the supine position or left lateral decubitus position with the transducer placed in the standard position, usually at the left fourth intercostal space lateral to the sternal margin. An M-mode scan was then performed from the aortic root to the apex of the left ventricle. The standard ECG (lead II) and phonocardiogram were simultaneously recorded on the echocardiogram.

Systolic time intervals were studied in 39 of 57 patients with artificial pacemakers. Twenty-six patients were in Group I, 6 in Group II, and 7 in Group III. Systolic time intervals were calculated from lead II of the electrocardiograms, phonocardiograms, and carotid pulse tracing. The tracing were recorded utilizing a Fukuda MCM-800 multichannel photographic recording system at a paper speed of 100 mm/sec. The left ventricular ejection time (LVET) was measured from the onset of the rapid stroke of the carotid pulse to the nadir of the dicrotic notch. The pre-ejection period (PEP) was calculated by subtracting LVET from Q-S₂ interval. The Q-S₂ interval was calculated from pacemaker artifact to the aortic component of the second heart sound. The rate correction of LVET was calculated pertaining to left ventricular ejection time index

Fig.1. Range of the maximal QRS vector in patients with pacemakers. Closed circles indicate echocardiographic abnormal septal motion (paradoxical or flat) during the ejection period.

(LVETI) using the method of Weissler and associates.¹⁸ The ratio of pre-ejection period to left ventricular ejection time (PEP/LVET) was also calculated.¹⁹ Five complexes were measured and averaged. The mean and standard deviation value were calculated and the data were subjected to student t-test.

RESULTS

ECG and VCG findings

The clinical, electrocardiographic and vectorcardiographic data, and echocardiographic findings are summarized in Table I.

All the pacemaker ECGs in Group I exhibited a LBBB type QRS morphology with left axis deviation. As illustrated in Fig. 1, the maximal QRS vector was oriented in the frontal plane between -35° and -145° . In left sagittal and horizontal planes, it was oriented between -20° and -80° , and between -40° and -130° , respectively. A typical example is reproduced in Fig. 2.

Although the 9 patients in Group II were also paced from the right ventricular apex, they showed a RBBB type QRS morphology with left

axis deviation. The maximal QRS vectors in the frontal, left sagittal and horizontal planes were oriented between -50° and -80° , between -85° and -110° , and between -10° and $+50^{\circ}$, respectively. Fig. 3 shows a representative case in Group II.

A RBBB type QRS morphology with right axis deviation was displayed by 8 of 9 patients with LV pacemakers in Group III. The maximal QRS vectors in the frontal, left sagittal and horizontal planes were between $+135^{\circ}$ and -150° , between -35° and $+80^{\circ}$, and between -125° and -170° , respectively. Fig. 4 shows a representative case in Group III. In one patient with LV pacemakers, a LBBB type QRS morphology with right axis deviation was observed in lead V_1 (Fig. 5). The maximal QRS vector was oriented to the right, inferiorly and posteriorly. On the basis of the ECG and VCG findings described above, the RBBB and LBBB type QRS morphology produced by RV pacing can thus be differentiated from the QRS morphology produced by LV pacing.

TABLE I CLINICAL, ELECTROCARDIOGRAPHIC AND VECTOR-

Case No.	Age & Sex	Clinical diagnosis	ECG findings prior to pacemaker insertion	
			Rhythm	QRS wave form
Group I				
1.	80 M	Id. Sync.	CHB	IVCD
2.	81 F	CAD, CHF	AVB—II/2	IVCD
3.	76 F	CAD, CHF	CHB	IVCD
4.	56 F	SSS, Sync.	SB	WNL
5.	71 M	SSS	SB	WNL
6.	80 M	CAD, CHF	CHB	IVCD
7.	47 F	Lupus erythematosus, CHF	CHB	IVCD
8.	67 M	Id. Sync.	Intermitt. CHB	RBBB
9.	68 M	SSS, CHF	SB	WNL
10.	81 F	Id. Sync.	CHB	IVCD
11.	84 F	CAD, CHF	SB	LBBB
12.	78 M	Id. Sync.	AVB—II/2	RBBB + LAH
13.	60 M	CAD	SB	RBBB + LAH + ASMI
14.	68 M	Id. Sync.	CHB	IVCD
15.	54 F	SSS, Sync.	SB	WNL
16.	67 M	CAD, CHF	CHB	LBBB
17.	64 F	Id. Sync.	Intermitt. CHB	RBBB + LAH
18.	58 F	Id. Sync.	AVB—II/2	WNL
19.	49 M	Id. Sync.	Intermitt. CHB	LBBB
20.	64 M	SSS, Sync.	SB	WNL
21.	53 M	CAD, SSS, Sync.	SB	AMI
22.	72 M	Id. Sync.	AVB—I	RBBB + LAH
23.	61 M	CAD, Sync.	CHB	LBBB
24.	70 M	Id. Sync.	CHB	IVCD
25.	65 F	Id. Sync.	CHB	IVCD
26.	84 M	Hypertensive heart dis., CHF	Intermitt. CHB	RBBB + LAH
27.	56 M	CAD, SSS, Sync.	SB	AMI
28.	65 F	CAD, CHF, Sync.	Intermitt. CHB	RBBB + IMI
29.	68 M	SSS	SB	WNL
30.	76 M	Id. Sync.	AVB—I	RBBB + LAH
31.	69 F	CAD, CHF	AVB—II/2	IMI
32.	56 M	Id. Sync.	Intermitt. CHB	WNL
33.	69 M	Hypertensive heart dis., CHF	CHB	IVCD
34.	44 M	CAD, CHF	AVB—II/2	IMI
35.	59 F	SSS	SB	WNL
36.	56 F	SSS, CHF	SB	WNL
37.	67 F	SSS, Sync.	CHB	IVCD
38.	84 F	CAD, CHF, Sync.	CHB	IVCD
39.	20 M	ASD (postop.), SSS	SB	RBBB

CARDIOGRAPHIC DATA AND ECHOCARDIOGRAPHIC FINDINGS (1)

Temporary or Permanent	QRS wave form in lead V_1	Maximal QRS vector ($^{\circ}$)			Echocardiogram	
		F	S	H	rapid initial posterior motion of the septum	septal motion during ejection period
P	LBBB	-90	-25	-90	+	anterior
T	LBBB	-135	-40	-130	+	anterior
P	LBBB	-145	-20	-115	+	anterior
P	LBBB	-35	-20	-60	+	anterior
T	LBBB	-35	-35	-70	+	anterior
P	LBBB	-105	-30	-105	+	anterior
P	LBBB	-60	-45	-60	+	anterior
P	LBBB	-80	-70	-80	+	anterior
T	LBBB	-110	-60	-120	+	anterior
T	LBBB	-85	-45	-90	+	anterior
T	LBBB	-90	-65	-85	+	anterior
T	LBBB	-60	-35	-65	+	anterior
T	LBBB	-100	-50	-105	+	anterior
P	LBBB	-65	-45	-65	+	anterior
P	LBBB	-95	-50	-105	-	anterior
P	LBBB	-55	-60	-30	-	anterior
P	LBBB	-90	-80	-60	-	anterior
T	LBBB	-70	-65	-45	+	flat
T	LBBB	-90	-80	-90	+	flat
P	LBBB	-85	-55	-85	+	flat
P	LBBB	-90	-55	-95	+	flat
T	LBBB	-110	-45	-110	+	flat
T	LBBB	-95	-60	-100	+	flat
P	LBBB	-30	-40	-60	+	flat
P	LBBB	-60	-50	-55	+	posterior
P	LBBB	-85	-25	-85	+	posterior
P	LBBB	-90	-55	-90	+	posterior
P	LBBB	-90	-35	-70	+	posterior
P	LBBB	-65	-65	-45	+	posterior
P	LBBB	-85	-45	-90	+	posterior
T	LBBB	-70	-40	-70	+	posterior
P	LBBB	-45	-25	-85	+	posterior
P	LBBB	-75	-45	-75	+	posterior
T	LBBB	-50	-25	-90	+	posterior
P	LBBB	-100	-55	-95	+	posterior
P	LBBB	-115	-55	-120	+	posterior
P	LBBB	-70	-40	-65	+	posterior
P	LBBB	-50	-55	-40	+	posterior
P	LBBB	-50	-45	-60	+	posterior

TABLE I CLINICAL, ELECTROCARDIOGRAPHIC AND VECTOR-

Case No.	Age & Sex	Clinical diagnosis	ECG findings prior to pacemaker insertion	
			Rhythm	QRS wave form
Group II				
40.	74 M	CAD, CHF	Atr. fib.	LAH + AMI
41.	67 M	CAD, CHF	CHB	IVCD
42.	67 M	Id. Sync.	Intermitt. CHB	RBBB + LAH
43.	66 M	SSS	SB	WNL
44.	82 M	Hypertensive heart dis., CHF	CHB	IVCD
45.	78 M	Congestive cardiomyopathy, CHF	Atr. fib.	RBBB
46.	91 F	CAD, SSS, Sync.	SB	ASMI
47.	81 M	CAD, SSS	SB	ALMI
48.	50 F	Postmyocarditis, SSS	SB	WNL
Group III				
49.	26 F	Sarcoidosis, Sync.	CHB	IVCD
50.	75 F	Hypertensive heart dis., CHF	CHB	IVCD
51.	45 M	Hypothyroidism, CHF, Sync.	CHB	IVCD
52.	49 M	Id. Sync.	Intermitt. CHB	LBBS
53.	55 M	Id. Sync.	CHB	IVCD
54.	41 M	CAD, Sync.	AVB—II/2	AMI
55.	46 M	Id. Sync.	CHB	IVCD
56.	62 F	Id. Sync.	CHB	IVCD
57.	77 F	CAD, CHF	CHB	IVCD

Abbreviations: ALMI = antero-lateral myocardial infarction; AMI = anterior myocardial infarction; AVB = atrio-ventricular block; CAD = coronary artery disease; CHB = complete heart block; IMI = inferior myocardial infarction; IVCD = intraventricular conduction disturbance; RBBB = right bundle branch block; SB = sinus bradycardia; SSS = sick sinus syndrome;

Echocardiographic findings

Thirty-six of 39 patients in Group I showed echocardiographic findings of abnormal septal motion. The abnormality consisted of a rapid initial posterior motion of the left side of the interventricular septum (IVS) occurring within 80 msec after the pacemaker artifact (arrow in Fig. 2). Paradoxical anterior or flat motion of the IVS during the ejection period was also observed in 24 patients.

These abnormal trends were also observed in Group II. A rapid initial posterior motion of the septum was observed in 7 of 9 patients and a paradoxical septal motion during the ejection period in 6 of 9 patients (Fig. 3).

In 8 of 9 patients with LV pacemakers (Group III), no rapid initial posterior motion of the IVS

was recorded following the pacemaker artifact and the IVS moved posteriorly during the ejection period (Fig. 4). However, one patients with a LBBB type QRS morphology in Group III showed a rapid initial posterior septal motion and a paradoxical septal motion during the ejection period (Fig. 5).

Systolic time intervals

The findings of heart rate, PEP, LVET, LVETI, and the PEP/LVET in each of the three groups of cases are summarized in Table II.

Mean value for systolic time intervals did not significantly differ between Group I and II, between Group I and III, and between Group II and III.

CARDIOGRAPHIC DATA AND ECHOCARDIOGRAPHIC FINDINGS (2)

Temporary or Permanent	QRS wave form in lead V_1	Maximal QRS vector ($^{\circ}$)			Echocardiogram	
		F	S	H	rapid initial posterior motion of the septum	septal motion during ejection period
P	prominent R wave	- 65	-100	+ 20	+	anterior
T	RBBB	- 70	- 95	+ 10	+	anterior
T	prominent R wave	- 75	- 85	- 10	+	anterior
T	RBBB	- 75	- 95	+ 25	+	anterior
P	RBBB	- 60	-100	+ 20	-	anterior
T	RBBB	- 65	- 90	+ 5	-	anterior
P	RBBB	- 80	-110	+ 50	+	posterior
T	RBBB	- 70	- 85	- 10	+	posterior
P	RBBB	- 65	- 90	+ 15	+	posterior
T	RBBB	- 50	-100	+ 15	+	posterior
P	LBBB	+150	+ 20	-125	+	anterior
P	RBBB	+175	+ 35	-150	-	posterior
P	prominent R wave	+175	+ 5	-145	-	posterior
P	RBBB	+170	+ 40	-160	-	posterior
P	RBBB	+135	+ 80	-170	-	posterior
P	RBBB	+135	+ 60	-150	-	posterior
P	RBBB	+160	+ 60	-160	-	posterior
P	RBBB	-165	- 20	-150	-	posterior
P	RBBB	-150	- 35	-145	-	posterior

ASD = atrial septal defect; ASMI = antero-septal myocardial infarction; Atr.Fib. = atrial fibrillation;
CHF = congestive heart failure; Id. = idiopathic sclerodegenerative disease of the conduction system;
LAH = left anterior hemiblock; LBBB = left bundle branch block; P = permanent pacemaker;
Sync. = syncope; T = temporary pacemaker; WNL = within normal limits.

DISCUSSION

It is well established that the morphology of the QRS complex during ventricular pacing depends on the site of the stimulation. While RV pacing yields a LBBB pattern, LV pacing results in a RBBB pattern¹⁻⁵. A RBBB pattern appearing in a patient with RV pacing indicates that the left ventricle depolarized early, despite the delivery of the pacemaker stimulus to the right ventricle.

If the catheter electrode, which is implanted into the great cardiac vein or which perforates the right ventricle, stimulates the surface of the left ventricle, a RBBB pattern with right axis deviation may appear during transvenous pacing^{4-10,13,14}. On the other hand, when the

catheter electrode is introduced into the middle cardiac vein, it can stimulate the posterior inferior wall of the left ventricle, producing a RBBB pattern with left axis deviation^{4,11-13}. Although this morphology is very similar to that found in cases in Group II, there was no clinical and roentgenographic evidence to indicate that this catheter malposition had occurred. In one case, an examination at autopsy confirmed a catheter position in the endocardium near the apex of the right ventricle.

It has been demonstrated that a RBBB type QRS morphology may be present even in cases with uncomplicated RV pacemakers^{8,15,20-23}. Although there are several possible ideas by which an uncomplicated RV pacing could produce a RBBB pattern, the mechanism involved in

Fig.2. Electrocardiographic, vectorcardiographic and echocardiographic findings in a 84 year-old woman with transvenous right ventricular pacemaker (Group I). The echocardiogram showed a characteristic abnormal initial septal motion (arrow) following the pacemaker artifact. Also, paradoxical septal motion was observed during the ejection period.

PHONO = phonocardiogram; IVS = interventricular septum; LVPW = left ventricular posterior wall

these phenomena remains unknown. Mower et al²⁰ suggested that the possibility that the pacemaker stimulus may have entered the right bundle branch and then travelled in a retrograde direction to the A-V junction and down the left bundle branch, with a resultant early depolarization of the left ventricle. Sodi-Pallares and Calder²⁴ proposed an interesting theory. They suggested that the pacemaker catheter might be stimulating the areas of the RV septum that were

functionally left ventricle, thereby depolarizing the left ventricle first. Lister et al²⁵ showed experimentally that electrocardiographic wave form was largely determined by the site of the pacemaker within the right ventricle. Barold et al⁸ explained that RBBB type QRS complexes developing during RV pacing appear to represent a RV activation delay caused by disease of the conduction system of the ventricle.

Prominent R wave in right precordial leads

Fig.3. An 91 year-old woman with transvenous right ventricular pacemaker (Group II). A RBBB pattern and left axis deviation were observed. The echocardiogram showed abnormal initial septal motion (arrow) following the pacemaker artifact. Normal septal motion was recorded during the ejection period. The position of the pacing catheter in the endocardium near the apex of the right ventricle was confirmed at autopsy.

was observed during RV pacing in patients with antero-lateral myocardial infarction²² and with posterior myocardial infarction^{26,27}. A prominent R wave in right precordial leads was also produced in a paced dog heart with posterior myocardial infarction²⁸. Accordingly, it seems to be possible to speculate that myocardial structural changes in the IVS and the ventricular wall might be responsible for the genesis of the RBBB pattern during RV pacing.

While the true origin of this phenomenon has not yet been resolved, efforts should be directed towards differentiating between perforation of the right ventricle and the other situations discussed above. In the present study, VCG findings provided useful information for such differential diagnosis. It can be reasonably postulated that the ECG wave forms produced by LV pacing might be equivalent to those produced by insertion of the catheter electrode through a perforat-

Fig.4. A 49 year-old man with left ventricular epicardial pacemaker (Group III). The electrocardiogram showed a RBBB pattern with right axis deviation. No rapid initial posterior motion of the septum was recorded and the septum moved posteriorly during the ejection period.

ed RV wall to the epicardial surface of the left ventricle. In the RBBB pattern demonstrated by RV pacing, the maximal QRS vector was oriented leftwards, superiorly and anteriorly, whereas, in the RBBB type QRS morphology demonstrated by LV pacing, the maximal QRS vector was directed to the rightwards, inferiorly and posteriorly. These differences in the direction of the maximal QRS vector may represent a key point for the differential diagnosis. Thus, a RBBB pattern with the maximal QRS vector directed leftwards and anteriorly may be indicative of uncomplicated RV pacing, whereas a

RBBB pattern with the maximal QRS vector oriented rightwards and posteriorly may be a warning sign of perforation of the right ventricle.

Useful information relating to the differential diagnosis of such complications were also provided by echocardiographic findings. A rapid initial posterior motion of the left side of the IVS during the early systole and/or anterior or flat motion of the IVS during the ejection period was almost exclusively indicative of RV pacing, regardless of the ECG wave form. However, there was one exceptional case in LV pacing (Group III) and on the basis of echocardiographic

Fig.5. A 26 year-old woman with left ventricular epicardial pacemaker (Group III). A LBBB pattern and right axis deviation were observed. The echocardiogram showed an abnormal initial posterior motion (arrow) following the pacemaker artifact. Paradoxical septal motion was observed during the ejection period.

findings, this case can not be differentiated from Group I. It showed a LBBB pattern with a rapid initial posterior septal motion and a paradoxical anterior septal motion during the ejection period. However, the direction of the maximal QRS vector in this case was directed inferiorly, which is in sharp contrast to that in Group I which was directed superiorly.

Recently several reports^{23,29-33} have described abnormal septal motion in patients with natural LBBB and in patients with pacemaker induced LBBB. The mechanism of such abnormal septal motion remains uncertain. McDonald²⁹ accounted for the abnormal initial posterior

septal motion during the pre-ejection period in natural LBBB on the basis of an asynchronous contraction of the left ventricle with early activation and contraction of the septum but with delay in activation and contraction of the LV free wall due to a block in the left bundle branch or its peripheral branches. Bevans and Rapaport³⁰ claimed that LBBB results in early pre-ejection posterior motion of the septum due to displacement from rising RV isovolemic pressure that exceeds the pressure developed by delayed LV contractions. Zoneraich et al.³³ indicated that the superior and posterior orientation of the artificially induced QRS loop causes early

TABLE II DATA OF SYSTOLIC TIME INTERVALS IN PATIENTS WITH ARTIFICIAL PACEMAKERS

		Group I	Group II	Group III	Statistical significance		
					Group I vs Group II	Group I vs Group III	Group II vs Group III
Number of cases		26	6	7			
Age	(yrs.)	*66.9 ± 10.1	78.3 ± 11.9	49.9 ± 14.6			
Heart rate	(/min)	69.8 ± 2.2	70.1 ± 1.2	70.4 ± 0.9	N.S.	N.S.	N.S.
PEP	(msec)	163 ± 35	158 ± 19	166 ± 14	N.S.	N.S.	N.S.
LVET	(msec)	252 ± 22	261 ± 17	250 ± 21	N.S.	N.S.	N.S.
LVETI	(msec)	368 ± 14	370 ± 12	364 ± 12	N.S.	N.S.	N.S.
PEP/LVET		0.65 ± 0.17	0.61 ± 0.10	0.66 ± 0.08	N.S.	N.S.	N.S.

PEP = pre-ejection period; LVET = left ventricular ejection time; LVETI = left ventricular ejection time index; N.S. = not significant. * = mean and standard deviation.

depolarization of the left ventricle, while the depolarization of the septum is not yet relaxed. Difference in ventricular activation may thus result in variation of septal motion.

This study also aimed to evaluate cardiac performance in patients with RBBB pattern induced by RV pacing. Systolic time intervals have proved to be a good index of myocardial contractility in patients with various heart diseases^{18,19}. The changes in the left ventricular ejection time and the pre-ejection period were significantly correlated with the level of cardiac output and stroke volume. The PEP/LVET lends a convenient expression of these changes in the systolic time intervals. Concerning to this non-invasive hemodynamic study, there were no significant differences in systolic time intervals between a LBBB pattern in RV pacing (Group I) and a RBBB pattern in RV pacing (Group II). These results suggested that a RBBB pattern induced by uncomplicated RV pacing does not require the repositioning of the catheter electrode hemodynamically. A previous study by Adolph et al.³⁴ suggested that in the presence of LBBB, PEP and PEP/LVET may not be as a reliable a reflection of LV performance as LVET. However, because of the paucity of studies of systolic time intervals in patients with pacemaker induced LBBB and RBBB pattern, the author decided to study PEP/LVET as well as LVET and emphasize the difference in value rather than the absolute value.

The influence of the site of ventricular pacing on cardiac performance has been investigated in experimental animals^{25,33-39}. The study of several investigators^{25,35-38} indicated that the

most favorable pacemaker site, in terms of left ventricular function, is localized to the left ventricular apex. However, other investigators³⁹⁻⁴¹ presented evidence that cardiac performance does not vary with the ventricular pacemaker site. Benchimol and Liggett⁴² reported that, in man, there are no hemodynamic differences between endocardial stimulation of the right and left ventricle at identical rates. Benchimol and Liggett⁴² and Barold et al.⁴³ found no appreciable differences in the cardiac performance when the outflow, midportion and inflow portion of the right ventricle were paced. The results of present study are in agreement with the findings of those investigators who demonstrated that sites of pacing do not significantly influence cardiac performance in man.

In summary, the following conclusions can be drawn from the present study.

- (1) A RBBB pattern in RV pacing could be differentiated from perforation of the right ventricle. The following findings may support uncomplicated RV pacing:
 - (a) the left and anterior orientation of the maximal QRS vector, and
 - (b) a rapid initial posterior septal motion during the early systole and/or a paradoxical anterior septal motion during the ejection period.
- (2) A RBBB pattern in uncomplicated RV pacing does not require the repositioning of the catheter electrode.
- (3) A LBBB pattern with right and inferior orientation of the maximal QRS vector would suggest perforation of the right ventricle.

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