Incidence of Positive Ventricular Late Potentials Differs in Postural Changes among Supine, Left, and Right Lateral Decubitus, and Prone and Sitting Positions in Brugada Syndrome

Koichiro Yoshioka, M.D., Ph.D.,* Mari Amino, M.D., Ph.D.,*
Mari Nakamura, M.D.,* Shigetaka Kanda, M.D.,* Yoshinori Kobayashi, M.D.,
Ph.D.,* Yuji Ikari, M.D., Ph.D.,* Makiyoshi Shima, M.D.,†
and Teruhisa Tanabe, M.D., Ph.D.†

From the *Department of Cardiovascular Medicine, Tokai University School of Medicine, Isehara, Japan; and
†Ebina General Hospital Cardiovascular Center, Ebina, Japan

Background: High-risk patients with Brugada syndrome (BrS) have inherent late potential (LP) fluctuations that might be explained by autonomic activity, electrolyte abnormality, and body temperature changes. However, the correlation between postural changes and LP determinates remains unknown.

Methods: Forty patients with BrS (38 men, 43.9 ± 13.5 years) and 15 controls (15 men, 42.4 ± 11.2 years) were enrolled. LP variations were investigated at five body positions using high-resolution ambulatory monitoring electrocardiography (HR-ambulatory ECG). The HR-ambulatory ECG was recorded for 3 hours and LP parameters (fQRSd, LAS40, and RMS40) were obtained for at least 15 minutes in each at the supine, left and right lateral decubitus, and prone and sitting positions.

Results: Determinate LP in the BrS group was significantly abnormal in all positions. Among the five body positions, positive LP were much more frequent in the supine and left and right lateral decubitus positions than in the prone and sitting positions and normalized in the last two positions in patients with BrS. RMS40 variance by postural change was significantly larger in the coved group than in the saddle back group. Determinate LP improved in the sitting position compared to the supine position in the coved group.

Conclusions: Positive LP findings normalized in the sitting position in patients in the coved BrS group with a resuscitation history, suggesting that depolarization instability might be related to the risk of fatal ventricular arrhythmia. Posture-induced LP variance should be examined using HR-ambulatory ECG analysis in patients with BrS.

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Brugada syndrome; conduction disorder; late potential; postural changes; high-resolution ambulatory electrocardiogram

Brugada syndrome (BrS) is characterized by a pattern of right bundle branch block or late r' and ST-segment elevation on right precordial electrocardiography (ECG) and a high incidence of

sudden death due to ventricular fibrillation (VF) or polymorphic ventricular tachycardia (VT) in structurally normal hearts.^{1–3} It has been reported that BrS is caused by repolarization and depolarization

Address for correspondence: Koichiro Yoshioka, M.D., Ph.D., Department of Cardiovascular Medicine, Tokai University School of Medicine, Shimokasuya 143, Isehara, 259-1193, Japan. Tel: +81-463-93-1121; Fax: +81-463-93-6679; E-mail: ko1@is.icc.u-tokai.ac.jp

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abnormalities.^{4,5} The repolarization abnormality in BrS is reflected by the morphological changes of the ST-segment⁶ or positive results of T-wave alternans⁷ and T-wave variability.⁸ On the other hand, depolarization abnormality is reflected in the late potential (LP) detected by signal-averaged ECG (SAECG).⁷ The existence of LP in BrS may support the presence of conduction abnormalities in the ventricular myocardium.

However, the examination of LP using SAECG is ordinarily performed a single time during the day. A negative LP may not be sufficient to confirm a low risk for the occurrence of life-threatening ventricular arrhythmia in BrS because it might be easily masked by awakening and have time-to-time or day-to-day variations. In recent years, 24-hour consecutive recordings have been used to assess continuous LP. Abe et al.⁹ compared the LP characteristics on Holter-based SAECG (FM-180S; Fukuda Denshi, Tokyo, Japan) between patients with BrS and arrhythmogenic right ventricular cardiomyopathy (ARVC) and found that dynamic daily LP variations were seen only in patients with BrS. This finding might imply that BrS has a stronger correlation with autonomic changes than ARVC.⁹ We also used high-resolution (HR) ambulatory monitoring (Spider View; Ela Medical, Paris, France) for patients with BrS over 24 hours and reported that high-risk patients had inherent daily LP fluctuations that differ from those that are characteristics of asymptomatic BrS.¹⁰ LP variability might be explained not only by autonomic activity but also by electrolyte abnormality, body temperature, and drug and food intake.^{11,12} However, the correlation between postural change and LP remains unknown. Using new posture sensor equipment connected to Holter ECG, coauthor Tanabe et al.¹³ clarified that QRS-ST segment changes were often produced by postural alterations. The aims of the present study were to investigate LP variations in multiple body positions using HR-ambulatory ECG and evaluate which postural positions could affect ventricular conduction disorders.

METHODS

Patient Population

Forty patients referred to Tokai University Hospital (Isehara, Japan) between January 2011 and April 2013, whose ECG showed BrS patterns

in the V₁-V₃ of the chest leads were enrolled in the present study. Specifically, the patients met the following criteria:¹⁴ spontaneous or drug-induced coved-type ST elevation (J point elevation ≥ 0.2 mV followed by a negative T wave) in at least two of the three right precordial leads (V₁ to V₃) on resting 12-lead ECGs; and no abnormal findings on physical examination, chest radiography, echocardiography, or serum electrolytes. Patients with suspected variant-form angina pectoris according to positive coronary angiographic observations with acetylcholine were excluded. Fifteen healthy gender- and age-matched volunteers were included as controls. This study was approved by the Tokai University Clinical Ethical Review Board and written informed consent was obtained from all subjects.

Recording and Analysis of HR-Ambulatory ECG

The LP was studied in a standard manner using HR-ambulatory ECG (FM-180S; Fukuda Denshi, Tokyo, Japan). The signals were acquired on the measurements of filtered vector magnitude using bipolar X, Y, and Z lead configuration (CC5R, ML, CB2). Signals of 200–300 beats were amplified, digitized, averaged, and filtered backward at a high band-pass frequency of 40 Hz. HR-ambulatory ECG was recorded for 3 hours continuously from 14:00 to 17:00. At least 15 minutes were spent recording in each LP at each of the five body positions (supine, left and right lateral decubitus, prone, and sitting). The room temperature during the examination was maintained at 25°C. Blood pressure (BP) and heart rate (HR) were automatically collected at the bedside (MP 30; Philips, Andover, MA, USA) soon after changing position. All examinations were made in the absence of antiarrhythmic drugs.

For the analysis, the onset and offset of the vector magnitude forms of the QRS waves were determined manually using SCM-8000 system software (Fukuda Denshi) and then confirmed separately by two experienced cardiologists blinded to the subjects' clinical statuses. For the LP evaluation, three indices were calculated at a noise level $\leq 0.5 \mu\text{V}$: filtered QRS duration (fQRSd), duration of the terminal low-amplitude signal $< 40 \mu\text{V}$ (LAS40), and root mean square voltage of the terminal 40 ms of the fQRS (RMS40). The finding was considered positive for LP when two of the

following three parameters were fulfilled: $fQRSd \geq 135$ ms (corrected- $fQRSd \geq 105$ ms), $LAS40 \geq 39$ ms, or $RMS40 < 15 \mu V$ defined by Fukuda Denshi. The variance ratios by postural changes in these parameters were calculated by the difference between the maximum values among the five positions and that of the supine position.

Statistical Analysis

Nominal scales in each group and position are shown as number (%). Metric scales in each group are presented in means $\pm$ SD. The statistical study was performed between two groups (BrS group and control group/coved group and saddle back group) or among the five positions (supine, left/right lateral decubitus, prone, sitting). Nominal values were compared using 2×2 chi-square, Yates chi-square, or Fisher tests, depending on the expected value. The two-sample *t*-test was used to analyze metric values.

RESULTS

Postural Fluctuation in Noninvasive Parameters

Fifteen healthy subjects (15 men, 42.4 ± 11.2 years old) were added as controls for comparison with the 40 patients with BrS (38 men, 43.9 ± 13.5 years old). The fluctuations of BP and HR are shown in Figure 1. Patients in the BrS group (left panel) and control group (right panel) showed similar responses in systolic and diastolic BP and HR among position changes. Although BP and HR changed little from the supine to left/right lateral decubitus positions, those parameters were significantly increased in the prone and sitting positions.

Representative vector waveforms of the LP analysis of patients with BrS and controls are shown in Figure 2. Both $fQRSd$ and $LAS40$ values were gradually decreased according to positional changes from supine to left and right lateral decubitus, prone, and sitting posture; in contrast, $RMS40$ values increased in the prone or sitting positions in both the BrS (upper panels) and control groups (lower panels). In this regard, patients with BrS showed positive LP in the supine and left and right lateral decubitus positions that changed to negative in the prone and sitting posture. On the other hand, the control group demonstrated negative LP in all five positions.

Numerical data of $fQRSd$, $LAS40$, and $RMS40$ in the five positions in BrS and control groups were shown in Table 1. These two groups showed a significant decrease in $fQRSd$ and $LAS40$ and a significant increase in $RMS40$ in the prone and sitting positions. Average $fQRSd$ and $LAS40$ values in the BrS group were significantly longer than those of control groups in all five positions, while average $RMS40$ values in the BrS group were significantly lower than those of control groups in all five positions. In both groups, noise values were gradually increased according to positional changes from supine to left and right lateral decubitus, prone, and sitting posture. However, there were no significance between two groups about noise levels. Regarding the variance ratio by postural changes in the three LP parameters, no difference was seen between groups in $fQRSd$ variance (5.4% vs 7.2%) or $LAS40$ (12.6% vs 18.6%). However, the $RMS40$ variance was smaller in the BrS group than in the control group (35.9% vs 53.0%, $P < 0.05$). In the BrS group, positive determinate LP ratios were 75–78% in the supine and left/right lateral decubitus positions and decreased in the prone (63%, $P < 0.05$) and sitting (55%, $P < 0.01$) positions compared with the supine position. In the control group, determinate LP ratios were 0–13% in all five positions. There were no significant differences in the incidence of positive LP ratios among the five positions in the control group. The incidence of a positive LP at each position was significantly higher in the BrS group than in the control group.

Patient Backgrounds in the Coved and Saddle Back Groups

The BrS patients were divided into two groups based on ST-segment elevation morphology in the V_1 – V_3 leads on 12-lead ECG: coved type ECG ($n = 15$) and saddle back type ECG ($n = 25$). Patient characteristics are summarized in Table 2. The ratio of resuscitation history was higher in the coved group than the saddle back group (20% vs 0%, $P < 0.05$). There were no significant differences among the two groups in age (44.3 ± 13.4 vs 43.6 ± 13.9 years), gender (100% vs 92%), family history of sudden death or BrS (27% vs 8%), syncopal episode (20% vs 20%), occurrence of paroxysmal atrial fibrillation (PAF) (20% vs 16%), or LA dilatation (20% vs 16%).

The J-point amplitude of lead Z in the cove group indicated less fluctuation by postural changes.

Figure 1. Fluctuations of blood pressure (BP) and heart rate (HR) by postural changes in patients with Brugada syndrome (BrS) and control groups.

However, in the saddle back group, J-point amplitude of the prone position was significantly larger than that of the other positions. In all but the prone position, the J-point amplitude of the coved group was significantly larger than that of the saddle back group. It was exceptional that only at prone position was the J-point amplitude higher in the saddle back group than in the coved group, and the amplitude indicated a significantly higher amplitude compared to that in the supine position ($P < 0.05$). Ten subjects (40%) in the saddle back group showed the conversion from saddle back ST morphology to coved ST morphology by postural change. A representative case is shown in Figure 3. The marked change in ST segment morphology is seen from the saddle back pattern in the supine position to the coved pattern in the prone position in lead Z, whereas in leads X and Y, no morphology changes are indicated by body position changes.

Fluctuations in BP, HR, and LP by Posture Changes in the Coved and Saddle Back Groups

The fluctuations of BP and HR in the coved and saddle back groups are shown in Figure 4. Both groups showed similar responses in systolic or diastolic BP and HR to position changes. BP and HR increased in the prone and sitting positions compared to the supine position ($P < 0.05$).

Numerical data of fQRSd, LAS40, and RMS40 in the five positions in coved and saddle back groups were shown in Table 3. These two groups showed a significant decrease in fQRSd and LAS40 and a significant increase in RMS40 in the prone and sitting positions. Average values of three parameters in the coved group were not significant compared with saddle back group in all five positions. In both groups, noise values were gradually increased according to positional changes from supine to left and right lateral decubitus, prone, and sitting posture. However, there were no significance between two groups about noise levels. Regarding the variance ratio by postural changes in the three LP parameters, no significant difference was seen between groups in fQRSd variance (6.2% vs 4.9%) or LAS40 (16.2% vs 11.0%). However, the RMS40 variance was larger in the coved group than the saddle back group (48.6% vs 31.5%, $P < 0.05$). In the coved group, positive LP ratios were higher (80–87%) in the supine and left and right lateral decubitus positions than in the prone (67%) and sitting (47%) positions ($P < 0.05$ and $P < 0.01$, respectively). In the saddle back group, positive LP ratios were 60–76% in all five positions and there was no significant difference in positive LP ratio seen by postural change. There were no significant differences in positive LP incidences in any position between two groups.

Figure 2. Representative magnitude vector waveforms of late potential (LP) in all five positions.

Figure 3. The morphology of the ST segment in leads X and Y did not indicate the specific elevation characterized as Brugada syndrome (BrS); however, the coved type ST change was revealed in the prone position on lead Z.

Table 1. Determinate LP in the BrS and Control Groups

	BrS Group (n = 40)	Control Group (n = 15)	[†] P Value (BrS vs Control)
LP parameters			
fQRS (ms)			
Supine	158.1 ± 11.8	140.3 ± 12.0 [†]	< 0.01
Left lateral decubitus	157.3 ± 13.6	136.5 ± 11.4 [†]	< 0.01
Right lateral decubitus	156.9 ± 14.3	138.1 ± 12.0 [†]	< 0.01
Prone	154.3 ± 12.9*	137.7 ± 13.7 [†]	< 0.01
Sitting	149.5 ± 12.6*	130.2 ± 9.2 ^{†*}	< 0.01
LAS40 μ V (ms)			
Supine	46.6 ± 11.7	34.3 ± 8.0 [†]	< 0.01
Left lateral decubitus	46.7 ± 10.6	33.1 ± 7.7 [†]	< 0.01
Right lateral decubitus	46.9 ± 11.7	33.0 ± 8.0 [†]	< 0.01
Prone	42.7 ± 11.7*	28.0 ± 8.8 ^{†*}	< 0.01
Sitting	41.0 ± 11.0*	27.9 ± 6.4 ^{†*}	< 0.01
RMS40ms (μ V)			
Supine	12.3 ± 7.5	28.1 ± 14.4 [†]	< 0.01
Left lateral decubitus	13.2 ± 8.8	28.5 ± 14.0 [†]	< 0.01
Right lateral decubitus	12.6 ± 8.2	29.3 ± 15.0 [†]	< 0.01
Prone	15.3 ± 9.0*	35.4 ± 15.6 ^{†*}	< 0.01
Sitting	16.7 ± 9.9*	43.0 ± 15.6 ^{†*}	< 0.01
Noise (μ V)			
Supine	0.24 ± 0.05	0.23 ± 0.05	n.s.
Left lateral decubitus	0.37 ± 0.12*	0.34 ± 0.10*	n.s.
Right lateral decubitus	0.38 ± 0.16**	0.37 ± 0.14**	n.s.
Prone	0.45 ± 0.16**	0.38 ± 0.23**	n.s.
Sitting	0.52 ± 0.17**	0.51 ± 0.25**	n.s.
Variance ratio by postural change			
fQRSd (ms)	5.4 ± 4.9%	7.2 ± 5.2%	n.s.
LAS40 μ V (ms)	12.6 ± 12.2%	18.6 ± 12.3%	n.s.
RMS40ms (μ V)	35.9 ± 16.4%	53.0 ± 8.9% [†]	< 0.05
Determinate LP			
Supine	30 (75%)	2 (13%) [†]	< 0.01
Left lateral decubitus	30 (75%)	2 (13%) [†]	< 0.01
Right lateral decubitus	31 (78%)	2 (13%) [†]	< 0.01
Prone	25 (63%)*	1 (7%) [†]	< 0.01
Sitting	22 (55%)*	0 (0%) [†]	< 0.01

*P < 0.05 vs Supine

**P < 0.01 vs Supine

BrS = Brugada syndrome; LP = late potential; fQRSd = filtered QRS duration; LAS40 = duration of the terminal low-amplitude signal < 40 μ V; RMS40 = root mean square voltage of the terminal 40 ms of the fQRS. Nominal scales in each group and position are shown as number (%). Metric scales in each group are presented in means $\pm$ SD. The statistical study was performed between two groups (BrS group and control group) or among the five positions (supine, left/right lateral decubitus, prone, sitting). Nominal values were compared using 2 $\times$ 2 chi-square, Yates chi-square, or Fisher tests, depending on the expected value. The two-sample *t*-test was used to analyze metric values. *Significant difference compared to the supine position. [†]Significant difference between the BrS and control groups. Values of P < 0.05 were considered significant.

DISCUSSION

Variances of determinate LP derived by postural changes were examined using HR-ambulatory ECG in patients with BrS. The major findings of the present study were as follows: determinate LP in the BrS group were significantly deteriorated at

all five positions compared to those in the control group; positive LP at the supine and left and right lateral decubitus positions became negative when posture was changed to prone or sitting position in the BrS group; RMS40 variance by postural change was significantly larger in the coved group than in the saddle back group; and

Table 2. Demographic Observation of Patients in Coved and Saddle Back Groups

	Coved Group (n = 15)	Saddle Back Group (n = 25)	[†] P Value (Coved vs Saddle Back)
Backgrounds			
Age (years)	44.3 ± 13.4	43.6 ± 13.9	n.s.
Male	15 (100%)	23 (92%)	n.s.
Family history	4 (27%)	2 (8%) [†]	n.s.
Resuscitation history	3 (20%)	0 (0%)	< 0.05
Syncopal episode	3 (20%)	5 (20%)	n.s.
Paf occurrence	3 (20%)	4 (16%)	n.s.
LA dilatation	3 (20%)	4 (16%)	n.s.
J-point amplitude in lead Z (mm)			
Supine	1.33 ± 1.19	0.64 ± 0.60 [†]	< 0.05
Left lateral decubitus	1.50 ± 0.77	0.86 ± 0.58 [†]	< 0.05
Right lateral decubitus	1.07 ± 0.59	0.94 ± 0.83 [†]	< 0.05
Prone	1.53 ± 0.94	1.68 ± 1.37 [†]	n.s.
Sitting	1.33 ± 1.04	0.66 ± 0.55 [†]	< 0.05

*P < 0.05 vs Supine

Family history = family history of sudden death or Brugada syndrome (BrS); Paf = proximal atrial fibrillation; LA = left atrium. Nominal scales in each group and position are shown as number (%). Metric scales in each group are presented in means ± SD. The statistical study was performed between two groups (coved group and saddle back group) or among the five positions (supine, left/right lateral decubitus, prone, sitting). Nominal values were compared using 2 × 2 chi-square, Yates chi-square, or Fisher tests, depending on the expected value. The two-sample *t*-test was used to analyze metric values. *Significant difference compared to the supine position. [†]Significant difference between the coved and saddle back groups. Values of P < 0.05 were considered significant. Values of P < 0.05 were considered significant.

Figure 4. Fluctuations of blood pressure (BP) and heart rate (HR) by postural changes in patients with coved and saddle back groups.

abnormal LP determinates in the sitting position were greatly improved compared to those in the coved group when the posture was changed to the

supine position. To our knowledge, this is the first report on the correlation between fluctuations in LP determinates and postural changes.

Table 3. Determinate LP Values of the Coved and Saddle Back Groups

	Coved Group (n = 15)	Saddle Back Group (n = 25)	[†] P Value (Coved vs Saddle Back)
LP parameters			
fQRS (ms)			
Supine	159.7 ± 9.1	156.4 ± 12.3	n.s.
Left lateral decubitus	158.5 ± 14.5	156.7 ± 13.2	n.s.
Right lateral decubitus	158.5 ± 12.6	154.8 ± 14.3	n.s.
Prone	154.7 ± 11.0*	153.6 ± 13.9*	n.s.
Sitting	149.8 ± 12.0*	149.1 ± 13.0*	n.s.
LAS40 μ V (ms)			
Supine	48.8 ± 11.5	43.7 ± 9.6	n.s.
Left lateral decubitus	49.6 ± 11.2	44.9 ± 10.4	n.s.
Right lateral decubitus	48.1 ± 12.1	43.9 ± 9.5	n.s.
Prone	46.3 ± 12.1	40.1 ± 10.6*	n.s.
Sitting	41.7 ± 11.2*	40.1 ± 10.5*	n.s.
RMS40ms (μ V)			
Supine	11.2 ± 8.4	13.2 ± 6.7	n.s.
Left lateral decubitus	10.9 ± 9.4	14.3 ± 8.5	n.s.
Right lateral decubitus	12.2 ± 10.1	13.4 ± 6.7	n.s.
Prone	14.6 ± 10.9*	15.9 ± 7.8*	n.s.
Sitting	16.3 ± 12.6*	17.4 ± 8.1*	n.s.
Noise (μ V)			
Supine	0.22 ± 0.04	0.25 ± 0.05	n.s.
Left lateral decubitus	0.36 ± 0.11*	0.38 ± 0.13*	n.s.
Right lateral decubitus	0.34 ± 0.11*	0.41 ± 0.18**	n.s.
Prone	0.40 ± 0.07**	0.48 ± 0.20**	n.s.
Sitting	0.50 ± 0.07**	0.53 ± 0.22**	n.s.
Variance ratio by postural change			
fQRSd (ms)	6.2 ± 4.6%	4.9 ± 4.9%	n.s.
LAS40 μ V (ms)	16.2 ± 12.4%	11.9 ± 11.2%	n.s.
RMS40ms (μ V)	48.6 ± 20.2%	31.5 ± 13.4% [†]	< 0.05
Determinate LP			
Supine	13 (87%)	17 (68%)	n.s.
Left lateral decubitus	13 (87%)	17 (68%)	n.s.
Right lateral decubitus	12 (80%)	19 (76%)	n.s.
Prone	10 (67%)	15 (60%)	n.s.
Sitting	7 (47%)*	15 (60%)	n.s.
*P < 0.05 vs Supine			
**P < 0.01 vs Supine			

BrS = Brugada syndrome; LP = late potential; fQRSd = filtered QRS duration; LAS40 = duration of the terminal low-amplitude signal < 40 μ V; RMS40 = root mean square voltage of the terminal 40 ms of the fQRS. Nominal scales in each group and position are shown as number (%). Metric scales in each group are presented in means $\pm$ SD. The statistical study was performed between two groups (coved group and saddle back group) or among the five positions (supine, left/right lateral decubitus, prone, sitting). Nominal values were compared using 2 $\times$ 2 chi-square, Yates chi-square, or Fisher tests, depending on the expected value. The two-sample *t*-test was used to analyze metric values. *Significant difference compared to the supine position. [†]Significant difference between the coved and saddle back groups. Values of P < 0.05 were considered significant. Values of P < 0.05 were considered significant.

ST Elevation by Postural Changes

The mechanism for ST elevation in BrS has been suggested by multiple investigators. Yan and Antzelevitch,⁶ using arterially perfused wedges of canine heart, reported that depression or loss of the action potential dome in the RV epicardium creates

a transmural voltage gradient that may be responsible for the ST-segment elevation observed in BrS. They also demonstrated that extrasystolic activity due to phase 2 reentry could arise in the intact wall of the canine RV and serve as a trigger for VT/VF. The ECG manifestations seen in congenital BrS are often concealed but can be unmasked or

modulated using sodium channel blockers, febrile state, vagotonic agents, α -adrenergic agonists, β -adrenergic blockers, tricyclic or tetracyclic antidepressants, a combination of glucose and insulin, hyperkalemia, hypokalemia, hypercalcemia, and alcohol and cocaine toxicity.¹² Mizumaki et al.¹⁵ reported that spontaneous augmentation of ST elevation in daily life occurred along with an increase in vagal activity in patients with BrS and that ST elevation was much more augmented in patients with VF than those without VF but with similar vagal tone.

Our data show that the J-point amplitude of lead Z in the coved group indicated less fluctuation by postural changes. However, in the saddle back group, the J-point amplitude in the prone position was significantly larger than that in the other positions. Ten patients (40%) in the saddle back group showed conversion to coved ST morphology by postural change from the supine to prone position. Arai et al.¹⁶ reported an interesting case in which the particular type of J-point and ST-segment elevation was induced when the patient experienced nausea and vomiting. It is proposed that this phenomenon originated from the vagal stimulation associated with the increase in abdominal pressure. That is, a similar mechanism seems to be engaged in the prone position in the saddle back patients. ST elevation also may occur soon after changing to the abdominal position because of vagal hypertonia. From the recording of HR-ambulatory ECG in our representative case of saddle back BrS, the coved ST morphology in the prone position immediately returned to a saddle back ST wave form after only three heart beats. This phenomenon might be the result that the predominant vagal tone intensity being rapidly replaced by the comparatively augmented sympathetic tone intensity. However, the early response of BP or HR, which reflect changes in sympathetic and vagal tone, just after postural changes could not be obtained because we did not measure them simultaneously with the posture changes.

LP Fluctuations and Autonomic Function

The posture changes from supine to left and right lateral decubitus or upright position provides a shift of blood volume in the circulatory system. The volume shifting to the peripheral organs from the heart decreases cardiac output and then increases

HR and BP. Our analysis of the autonomic functional perspective suggests that the supine position facilitates vagal activity, whereas the sitting and standing positions create sympathetic hypertonia. In earlier studies, analyses of heart rate variability showed that the low- and high-frequency powers were lower in patients with BrS than in controls.^{12,17} These results suggest that the vagal activity consistently decreased in patients with BrS. Kasanuki et al.¹⁸ reported that HR spectral analysis just before VF episodes in patients with BrS showed a sudden increase in high-frequency power, a marker of vagal activity. Patients with BrS had lower HR during the day and higher HR during at night compared to controls. This finding means that there was a lack of circadian variation in the heart rate variability, which might contribute to the pathogenesis of life-threatening arrhythmias.

Our results showed that BP and HR changed little from the supine to lateral decubitus position but significantly increased in the prone or sitting positions in both patients with BrS and controls. Three LP parameters were also changed by postural changes. The variances of RMS40 were smaller in the patients with BrS than in the control patients. These observations suggest that decreased autonomic activity might be involved with the formation of conduction delays in BrS. However, the variance of RMS40 by postural change was larger in the coved group than in the saddle back group. This result was unexpected, and the reason for the larger fluctuations in the saddle back group remains unclear. Further examinations will be required to elucidate this point.

Conclusion

The incidences of positive LP findings were diminished in the sitting position in patients with coved BrS who had a history of resuscitation. This result suggests that ventricular and atrial depolarization instability might be related to the risk of fatal ventricular arrhythmia. LP variance by postural changes should be considered, and HR-ambulatory ECG analysis would be useful for this purpose.

Study Limitations

- (1) The number of patients in the present study was quite limited. Further data are needed

to improve the usefulness of noninvasive prognostic markers for identifying high-risk patients with BrS.

- (2) The subjects in our study were ≥ 40 years of age, which might reflect a limited scope of this technique.
- (3) It has been reported that repolarization and depolarization abnormalities in the ventricle in patients with BrS. Kofune et al.¹⁹ reported that abnormal interatrial conduction and steep restitution of action potential duration may contribute to the atrial arrhythmogenicity seen in BrS. Noninvasive repolarization markers such as T-wave alternans or T-wave variability and electrophysiological markers such as action potential duration should also be investigated.

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