SILENT ZONE ON LORENZ PLOTS OF THE VENTRICULAR RESPONSE BEFORE TERMINATION OF PAROXYSMAL ATRIAL FIBRILLATION

— Report of a Case —

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An ambulatory 24 h Holter electrocardiogram was recorded during paroxysmal atrial fibrillation in a 67-year-old man. His paroxysmal atrial fibrillation terminated spontaneously approximately 12 h after the start of recording. The RR variability of this Holter recording was studied using Lorenz plots, frequency domain analysis, and time domain analysis. A silent zone appeared on the Lorenz plots beginning a few hours before the termination of his attack. The coefficient of variance (CV) and the power of the high-frequency component of RR variability (HF) gradually increased toward the termination. The silent zone was closely related to the functional refractory period of the atrioventricular node estimated from the Lorenz plots, and the functional refractory period was significantly correlated with the CV and HF power of RR variability. This case suggests that a silent zone on Lorenz plots reflects increased parasympathetic tone. In addition, such a silent zone may be useful for predicting the course of paroxysmal atrial fibrillation and for evaluating the role of the autonomic nervous system in this condition. (Jpn Circ J 1994; 58: 676—682)

Atrial fibrillation is considered an absolute arrhythmia, which indicates that the ventricular response shows no regularity on routine examinations. However, recent studies have detected a non-random ventricular response in atrial fibrillation using an autocorrelation technique and computer calculation.

The atrial firing mode and the conductivity of the atrioventricular node (AVN) have long been considered to affect the ventricular response in atrial fibrillation. Both of these factors are in turn influenced by other factors, including autonomic nervous activity. Therefore, the application of new techniques to carefully assess the ventricular response in atrial fibrillation may provide new information regarding the regulation of ventricular responses by the autonomic nervous system.

We used the Lorenz plot method to study a patient with paroxysmal atrial fibrillation (Paf) which terminated spontaneously, and obtained certain characteristic findings.

CASE REPORT

The patient was a 67-year-old man with essential hypertension who had suffered from occasional attacks of Paf for 6 years.

Key words:
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Echocardiography revealed no organic heart disease and normal left ventricular contraction. He had received captopril (37.5 mg/day), doxazosine mesilate (2 mg/day), and digoxin (0.25 mg/day) for about 3 years. He was admitted with slight palpitations on exercise. The admission 12-lead electrocardiogram (ECG) showed atrial fibrillation with a rapid ventricular response of 120—140 beats/min (Fig. 1). Ambulatory 24 h Holter monitoring (SM-28, FUKUDA Densi Co. Ltd., Tokyo, Japan) was subsequently performed beginning at 10:17.

The recorded data were analyzed with a Holter ECG analyzer (DMW9000H, FUKUDA Densi Co.) and transmitted to a personal computer (98FX, NEC Co. Ltd., Tokyo, Japan). The relationship between the coupling interval to the preceding RR interval and the RR variability (Lorenz plot) were analyzed by the computer. In Lorenz plot analysis, ventricular premature contractions (VPC) were automatically excluded by the Holter analyzer and manual correction before data transmission. The spectral analysis of RR variability was conducted without special handling for VPC, because the rate of VPC was low (857/24 h) and almost constant (65/h).

**Conventional Holter Analysis**

Paf terminated spontaneously at 22:58 on the Holter ECG. Fig. 2 shows 10 sec Holter recordings of lead CM5 obtained at hourly intervals until the termination of Paf. Ventricular premature contractions occurred from the start of the recording to the termination of Paf. Neither the real-time hourly recordings nor the compressed recordings showed any changes in the irregularity of the ventricular response.

**Lorenz Plot**
Whole-day Lorenz plots showed a typical atrial fibrillation pattern (Fig. 3). Both the ventricular and the preceding ventricular coupling (RR) intervals varied within 300–1000 msec during Paf, so the plots showed a uniform distribution (shaded area in Fig. 3).

Fig. 4 shows a series of hourly Lorenz plots. A silent zone, that was defined as an empty area, appeared towards the termination of Paf (arrow in panel L of Fig. 4). The same silent zone can also be seen in panel G.

The hourly changes in the functional refractory period (FRP) of the AVN, as estimated by the shortest coupling interval on the Lorenz plots are shown in Fig. 5. The longest FRP of 275 msec was obtained, and the FRP showed an initial peak (16:17), just prior to cessation of Paf (22:17, Fig. 5). The silent zone seemed to appear as the FRP increased.

**Mean Ventricular Rate (HR) and the Coefficient of Variance of HR (CV)**

Although CV value have has only been evaluated in sinus rhythm, it seems reasonable to assume that RR variability would re-

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**Fig.3.** Whole-day Lorenz plots. The X-axis indicates the preceding RR interval and the Y-axis indicates its coupling interval. FRP, functional recovery period of the atroventricular node.

**Fig.4.** Hourly Lorenz plots. The arrow marked S indicates a typical silent zone. Another silent zone can be noted in panel G.
respond to autonomic nervous activity in atrial fibrillation as it does in sinus rhythm. Accordingly, both the mean HR and its CV were calculated from the data on hourly total ventricular responses (Fig. 6). The mean HR gradually decreased from 148 beats/min to 105 beats/min towards the termination of Paf. A sudden decline in mean HR was noted in the hourly recordings starting at 16:17 and 22:17, and the minimum value was obtained in the 22:17 recording (upper left panel in Fig. 6). In contrast, CV increased gradually towards the termination of Paf. CV also showed two peaks, which occurred.
in the hourly recordings starting at 16:17 and 21:17. The maximum value was noted in the hourly recording starting at 21:17 (lower left panel in Fig. 6). The mean and maximum values of CV were 26.3±1.2 % and 28.2%, respectively.

The High-Frequency Power of RR Variability

Frequency domain analysis of the hourly RR intervals during Paf was performed by computer using fast Fourier transformation (FFT). Sampling was performed every 512 beats and Hanning window calculations were employed. The high frequency (HF) range was defined as 0.15—0.40 Hz, a common standard. In our patient, the mean HF power during atrial fibrillation was 7000±10 msec². The time course of changes in the HF power was similar to that of the CV and the FRP (lower right panel in Fig. 6). The HF changes had two peaks in the hourly recordings starting at 16:17 and 21:17, and gradually increased towards the termination of Paf. The highest HF peak (11,800 msec²) was obtained in the 21:17 recording (lower right panel in Fig. 6), at which time Paf ceased.

The time course of LF power was different than those of the other parameters. Although the LF power also showed 2 peaks, the highest peak was obtained in the recording from 20:17, 1 h before the HF and CV peaks.

Relationship of FRP to the mean HR, CV, and HF Power

When the relationships among these parameters were examined (Fig. 7), the mean HR had a close negative linear correlation with FRP. In contrast, CV and HF power showed a close positive linear correlations with FRP.

DISCUSSION

In the present patient, Holter ECG analysis demonstrated that 1) a silent zone appeared on the Lorenz plots near the termination of Paf, 2) the silent zone was closely related to the FRP, and 3) HF power and the CV both increased towards the termination of Paf. Thus, the present case indicates that a silent zone on hourly Lorenz plots may reflect increased parasympathetic activity and can be useful for predicting the course of Paf.

A silent zone appeared on the Lorenz plots towards the termination of Paf. To the best of our knowledge, this is the first report of such a silent zone on Lorenz plots during Paf. When there is no regulatory mechanism associated with the ventricular response during atrial fibrillation, the Lorenz plots are completely random, and there should be no silent zone. Therefore, the presence of a silent zone indicates that some regulatory mechanism was present during Paf in our patient. To detect regularity of the ventricular response during atrial fibrillation is extremely difficult by conventional methods. In fact,
routine Holter analysis did not reveal any regularity in the present case. However, hourly Lorenz plots provided a useful method for detecting a regularity of the ventricular response.

In the present case, the silent zone was closely related to the FRP. It is reasonable to assume that the shortest coupling interval on a Lorenz plot obtained during atrial fibrillation represents the FRP of the AVN\textsuperscript{9,10}. The silent zone appeared on the plots when the FRP was $>270$ msec. Therefore, our results suggest that the silent zone reflected prolongation of the FRP.

In our case, the FRP also correlated significantly with the CV, and changed in association with the HF power. Moreover, the silent zone appeared in association with HF peaks. Many studies\textsuperscript{11,12} have revealed that both the CV and the HF power represent parasympathetic nervous activity in sinus rhythm. Although the relationship between parasympathetic activity and the HF power in atrial fibrillation was not fully clarified, parasympathetic activity may affect HF power as does the sinus rhythm. Based this assumption, the prolongation of the FRP in our patient may have been due to parasympathetic enhancement. Although the factors that increased parasympathetic tone in this case are unknown, its increase towards the termination of Paf probably played a role in the cessation of fibrillation.

The mechanism by which increased parasympathetic activity produces a silent zone is also unclear. However, two factors may contribute to the silent zone; i.e., an increase in the concealment associated with an increase in the atrial firing rate induced by parasympathetic enhancement\textsuperscript{13} and a reduction in AVN conduction by parasympathetic enhancement. The fact that the silent zone appeared in association with relatively short RR intervals seems to be consistent with this explanation.

The FRP did not change concomitantly with the LF power. Recent studies\textsuperscript{14} have indicated that the LF power represents relative sympathetic activity related to parasympathetic activity. Therefore, changes of sympathetic tone did not appear to play a substantial role in the production of the silent zone or in the cessation of Paf in our patient.

Several limitations are apparent in this report. RR variabilities were observed even in this case with atrial fibrillation. Several studies have suggested that atrial fibrillation shows circadian fluctuations in RR variability\textsuperscript{15}. This circadian fluctuation was consistent with circadian changes in autonomic nervous activity. Therefore, it seems quite reasonable to hypothesize that RR variability in atrial fibrillation is affected by autonomic nervous activity as in sinus rhythm. The present results concerning the time course of indices of RR variabilities would not be inconsistent with this hypothesis.

In summary, the present case suggests that a silent zone on a Lorenz plot reflects increased parasympathetic tone, and that this silent zone is a useful visual indicator for predicting the termination of Paf.

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