ORIGINAL ARTICLE

Effects of Preexcitation Syndrome on Terminal QRS Vector Observed in Spatial Vector

Qingru Wang, M.D.,* Yang Chen, M.D.,† Renguang Liu, M.D.,* and Qinghua Chang, M.D.*

From the *Cardiovascular Institute, The First Affiliated Hospital, Liaoning Medical University, Jinzhou, Liaoning Province, China and †Department of Cardiovascular Medicine, Weifang Traditional Chinese Hospital, Weifang, Shandong Province, China

Background: Preexcitation syndrome could affect terminal QRS vector, which is not emphasized in clinic. In this study, we made a comparison between vectorcardiogram (VCG) before and after ablation to observe the change of terminal QRS vector. Furthermore, the relationship between the change of terminal QRS vector and accessory pathway (AP) as well as the change of initial QRS vector (delta vector) was analyzed.

Methods: Thirty patients who were proved to have a single AP by ablation were included. All patients were divided into seven groups based on the AP location. Comparison between VCG before and after ablation was made to observe the change of terminal and delta vector. The relationship between the change of terminal QRS vector and AP location as well as delta vector was analyzed.

Results: (1) All 30 patients had a change in terminal QRS vector (elevation and/or azimuth) in comparison to postablation VCG. (2) The change of terminal QRS vector was related to delta vector and AP location. The agreement and consistency between the change of terminal QRS vector and delta vector were 91.65% and 0.856 ($P < 0.01$), respectively.

Conclusions: (1) Both initial and terminal QRS vector are affected by the antegrade conduction of AP. The change of terminal QRS vector is related to the AP location and delta vector. (2) The effect of preexcitation syndrome on QRS terminal vector is shown as more intuitive and easy in spatial vector by comparison with electrocardiogram, which is helpful for the diagnosis of atypical preexcitation and localization of AP.

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In preexcitation syndrome, the electrocardiogram (ECG) diagnosis and localization of accessory pathway (AP) are mainly based on delta wave. Preexcitation syndrome with AP capable antegrade conduction could be divided into overt and latent according to the presence or absence of delta wave.^{1–3} However, both the initial QRS vector and terminal QRS vector could be modified by the antegrade conduction of AP.^{4–6} In patient with "latent preexcitation," we have recorded a new type preexcitation (incomplete latent preexcitation) which mainly

manifest the change of terminal QRS vector.^{7,8} Furthermore, the presence of a delta wave indicates that AP conduction is faster than AV node conduction. The change of terminal QRS vector is the hallmark of antegrade conduction via the AP.

METHODS

Materials

Thirty patients who were proved to have a single AP by ablation formed the subject of this study.

Address for correspondence: Renguang Liu, The Cardiovascular Institute, The First Affiliated Hospital of Liaoning Medical University, Renmin Street, Jinzhou, Liaoning Province 121001, China. Fax: 0086-0416-4197105; E-mail: lijunchang0802@163.com

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Figure 1. Measurements of the elevation and azimuth. (A) Elevation = the angle between the vector and the axis (Y-axis) perpendicular to the transverse plane, defined as zero when pointing downwards and 180° when pointing in the cranial direction. (B) Azimuth = the angle of the projection of the vector in the transverse plane (X-Z plane), defined as zero when the vector is pointing to the left. Forward vector directions are designated 0~ +180° and backward vector directions 0~ –180°.

Table 1. The Effect of Preexcitation Syndrome on Terminal QRS Vector (n = 30)

Change of Terminal QRS Vector		Elevation		
		↑ (16)	↓ (9)	Invariably (5)
Azimuth	↑ (14)	4	7	3
	↓ (13)	10	1	2
	Invariably (3)	2	1	0
Kappa statistic			–0.379	
P value			0.106	

↑ = Increase of elevation or increase of the absolute value in azimuth.
↓ = Decrease of elevation or decrease of the absolute value in azimuth.
Invariably: The change of terminal QRS vector was < 10° emerging in the elevation and/or azimuth.

There were 19 males and 11 females, with a mean age of 39.37 ± 16.30 years (ranging from 12 to 74 years). All patients were divided into seven groups according to the AP location⁹: eight patients with left anterior AP (LA, beyond 5 cm of the ostium of coronary sinus); five patients with left lateral AP (LL, within 3–5 cm of the ostium of coronary sinus); eight patients with left posterior AP (LP, within 3 cm of the ostium of the coronary sinus); two patients with right lateral AP (RL, 8:30–9:30 position on the tricuspid annulus); four patients with right posterior AP (RP, 6:00–8:30 position on the tricuspid annulus); two patients with right midseptal AP (RMS, at the tricuspidannulus between the electrode catheter recording the His bundle electrogram and that marking the coronary sinus ostium); six patients with right posteroseptal AP (RPS, inferior or posterior to the coronary sinus ostium as far as the 6 o'clock position on the tricuspid annulus).

Electrophysiologic Study and Radiofrequency Catheter Ablation

All antiarrhythmic drugs were discontinued for ≥5 half-lives. All patients gave informed consent. Details concerning electrophysiological study and radiofrequency catheter ablation (RFCA) techniques for AP have been described previously.⁹

Analysis of Terminal QRS Vector

SCA-II type three-dimensional vectorcardiogram (VCG) (Beijing Cadiz Medical Technology Co., Ltd, Beijing, China) was applied to observe the change of terminal QRS vector. Before and after ablation, a baseline 12-lead ECG and VCG were recorded (paper speed 25 mm/s, gain 10 mm/mV). The ECG and VCG were recorded on a Wilson system and Frank orthogonal lead system, respectively. In order to exclude the effect of respiration on QRS

Table 2. The Change of Terminal QRS Vector in Vectorcardiogram (n = 30)

		LA (n = 8)	LL (n = 5)	LP (n = 3)	RL (n = 2)	RP (n = 4)	RMS (n = 2)	RPS (n = 6)
Elevation	↑	1 (12.5)	0 (0.0)	2 (66.7)	2 (100.0)	4 (100.0)	2 (100.0)	5 (83.3)
	↓	6 (75.0)	3 (60.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Invariably	1 (12.5)	2 (40.0)	1 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (16.7)
Chi-square					25.097			
P value					0.014			
Azimuth	↑	6 (75.0)	4 (80.0)	1 (33.3)	0 (0.0)	1 (25.0)	1 (50.0)	1 (16.7)
	↓	1 (12.5)	1 (20.0)	1 (33.3)	2 (100.0)	3 (75.0)	0 (0.0)	5 (83.3)
	Invariably	1 (12.5)	0 (0.0)	1 (33.3)	0 (0.0)	0 (0.0)	1 (50.0)	0 (0.0)
Chi-square					19.704			
P value					0.073			

↑ = Increase of elevation or increase of the absolute value in azimuth.

↓ = Decrease of elevation or decrease of the absolute value in azimuth.

Invariably: The change of terminal QRS vector was < 10° emerging in the elevation and/or azimuth.

() Including in the brackets is percentage.

LA = left anterior accessory pathway; LL = left lateral accessory pathway; LP = left posterior accessory pathway; RL = right lateral accessory pathway; RP = right posterior accessory pathway; RMS = right midseptal accessory pathway; RPS = right posteroseptal accessory pathway.

Table 3. Relationships between the Change of Terminal QRS Vector and the Change of Initial QRS Vector in Vectorcardiogram (Elevation, n = 30)

Initial QRS Vector		Elevation		
		↑ (17)	↓ (8)	Invariably (5)
Terminal QRS vector elevation	↑	16	0	0
	↓	0	8	1
	Invariably	1	0	4
Chi-square			45.122	
P value			0.000	

↑ = Increase of elevation.

↓ = Decrease of elevation.

Invariably: The change of terminal QRS vector was < 10° emerging in the elevation and/or azimuth.

complex, the ECG and VCG were recorded when the patient was breath holding (three complexes were recorded). The measured data were mean value calculated from three QRS complexes.

Measured Value

(1) QRS initial vector: the spatial orientation (elevation and azimuth) of initial 30 ms QRS vector was observed. Elevation of initial 30 ms QRS vector is the angle between the 30 ms QRS vector and an axis perpendicular to the horizontal plane, zero being the vector directed downward (a scale from 0° to 180°), see Figure 1A. Azimuth of initial 30 ms QRS vector is the angle between the projected of initial 30 ms QRS vector on the horizontal plane (X-Z) and the left extremity of the X-axis, zero

being the vector pointed to the left. Forward vector motions are defined as 0–180°, and backward vector motions as 0–180°,^{10–12} see Figure 1B. (2) Terminal QRS vector: spatial orientation (elevation and azimuth) of terminal 20 ms QRS vector was observed. The measurement method of terminal 20 ms QRS vector was same as initial 30 ms QRS vector. Criteria for the change of terminal QRS vector were ≥10° change emerging in the elevation and/or azimuth.

Analytical Method

Comparison between VCG before and after ablation was made to observe the change of terminal and initial QRS vector. Furthermore, the relationship between the change of terminal QRS

Table 4. Relationships between the Change of Terminal QRS Vector and the Change of Initial QRS Vector in Vectorcardiogram (Azimuth, n = 30)

Initial QRS Vector		Azimuth		
		↑ (15)	↓ (13)	Invariably (2)
Terminal QRS vector Azimuth	↑	13	1	0
	↓	1	12	0
	Invariably	1	0	2
Chi-square			40.690	
P value			0.000	

↑ = Increase of the absolute value in azimuth.

↓ = Decrease of the absolute value in azimuth.

Invariably: The change of terminal QRS vector was < 10° emerging in the elevation and/or azimuth.

Table 5. The Consistency between the Change of Terminal QRS Vector and Delta Wave Vector (n = 30)

Initial QRS Vector		Elevation	Azimuth	Mean
Terminal QRS vector	Agreement	93.3%	90.0%	91.65%
	Kappa statistic	0.887	0.825	0.856
	P value	<0.01	<0.01	<0.01

vector and AP location as well as initial QRS vector was analyzed.

Statistical Analysis

Enumeration data are presented as rate. For categorical variables, chi-square analysis of contingency table was applied. When the $N < 40$ or $T < 1$, Fisher's exact 2-tailed test was applied. The coincidence and concordance were applied to observe the relationship between the change of terminal QRS vector and initial QRS vector. A P value < 0.05 was considered statistically significant. Conventional arbitrary divisions for interpreting the κ ratio are: lower than 40% is negligible, 40–60% is fair, 60–80% is good, and over 80% is excellent.¹³

RESULTS

The Effect of Antegradely Conducting AP on Terminal QRS Vector

There was a change in terminal QRS vector (elevation and/or azimuth) in all 30 patients before ablation by comparison with postablation VCG. Out of 30 enrolled patients, 25 had a change in elevation and 27 had a change in azimuth (Table 1).

Relationship between the Change of Terminal QRS Vector and AP Location

The change of terminal QRS vector was related to AP location. (1) An increase of absolute value in azimuth (representing the terminal QRS vector shift to right) was found in 11 of 16 patients with left-side AP (LA, LL, LP). A decrease of elevation was usually observed in patients with LA and LL AP. Inversely, an increase of elevation was usually observed in patients with LP AP. (2) Of 14 patients with right-side AP, 10 had a decrease of absolute value in azimuth. Thirteen of the 14 patients with right-side AP (RL, RP, RMS and RPS) had an increase in elevation (Table 2).

Relationship between the Change of Terminal QRS Vector and the Change of Initial QRS Vector (Delta Vector)

In spatial orientation, the change of terminal QRS vector was in agreement with the change of initial QRS vector. When the elevation of initial QRS vector increases, the degree of elevation in terminal QRS vector increase too (Table 3); when the absolute value of azimuth of initial QRS vector increases, the absolute value of azimuth of terminal QRS vector increases too (Table 4). The agreement between the change of terminal QRS vector and

Figure 2. The delineation of the mechanism of preexcitation syndrome with overt bypass. (A) The activation prematurely depolarizes the ventricle via accessory pathway forming the delta wave (the shortened extent of PR interval is equal to the duration of delta wave). (B) The onset of the normal conduction is the termination of delta wave, but the bypass conduction is continuous (masked in ECG). (C) The activation conducts through the bypass and normal conduction system fuses into the monophyletic ventricular fusion, with delta wave in its initiation and the deformation in its termination.

Figure 3. The ECG before and after ablation of a 46-year-old female patient (right posteroseptal accessory pathway). (A) Limb lead. (B) Chest leads. Top panel shows the ECG before ablation; Bottom panel shows the ECG after ablation. ↑ and ↓ show the leads with an obvious change in terminal QRS vector.

the change of initial QRS vector was 91.65%. The consistency between the change of terminal QRS vector and the change of initial QRS vector was 0.856 (Table 5).

DISCUSSION

The finding of this study further confirmed that the antegradely conducting AP could affect the

Figure 4. QRS-T vector loops of the patient in Figure 3. (A) The vectorcardiogram before ablation. (B) The vectorcardiogram after ablation. ↗ shows terminal QRS vector direction. The antegrade conduction of accessory pathway not only affects the initial QRS vector, but also changes the terminal QRS vector.

terminal QRS vector, the change of terminal QRS vector was related to the change of initial QRS vector and AP location.

Mechanism of the Effect of Preexcitation Syndrome on Terminal QRS Vector

Ventricular preexcitation should be understood as activation of the ventricles occurring over two atrioventricular (AV) pathways, resulting in a fusion QRS complex. Theoretically, if the ventricular fusion beat is present the QRS terminal vector and morphology should be changed. In this article, we observed 30 patients with overt preexcitation syndrome and compared the VCG before and after ablation. The finding of this study further confirmed that both initial QRS vector and terminal QRS vector could be affected by antegrade conduction of AP. The mechanism of ECG characteristics in patients with typical

preexcitation syndrome is that the AP conduction is faster than the AV node conduction,¹⁴ resulting in the part of the ventricle that is directly connected to the AP is slowly depolarized first, producing a delta wave and shortened PR interval (ventricular conduction velocity 400 mm/s), see Figure 2A. Once the impulse travels from the normal pathway down to the ventricle, the rapid depolarization starts and the delta wave ends (Purkinje fiber conduction velocity 4000 mm/s), see Figure 2B. The end of delta wave is the onset of ventricular depolarization via normal pathway (not the end of the ventricular depolarization via AP), during this time, ventricular depolarization via the AP still continues until the end of the ventricular depolarization (Fig. 2C). So, the antegrade conduction of AP not only affects the initial QRS vector, but also changes the terminal QRS vector (Figs. 3 and 4). As the change of terminal QRS vector results from the antegrade

conduction of AP, so it is related to the AP location and delta wave.

Relationship between the Change of Terminal QRS Vector and Initial QRS Vector as well as AP Location

The finding of this study suggested that the change of terminal QRS vector was related to the change of initial QRS vector. The agreement between the change of terminal QRS vector and the change of initial QRS vector was 91.65%, the consistence between the change of terminal QRS vector and the change of initial QRS vector was 0.856. A clear relationship among these three parameters suggests that the analysis of terminal QRS vector (comparing with ECG during atrioventricular reentrant tachycardia [AVRT]) is not only helpful for the diagnosis of preexcitation syndrome with not evident delta wave but also be helpful for localization of AP. The findings of this study (Table 2) confirm that: when the absolute value of azimuth increases (terminal QRS vector shifts to right showing a decrease in the amplitude of S wave in lead V_1), we should expect the presence of left-side AP, or vice versa. If the elevation decreases (terminal QRS vector shifts to inferior showing an increase in the amplitude of R wave in lead aVF), the AP is located at the anterior region. Lau et al.¹⁵ observed the change of terminal QRS vector in lead V_1 and proposed the conclusion that an rSr' pattern in lead V_1 and rS pattern during AVRT should raise suspicion of the possible existence of an antegradely conducting left-side AP. The mechanism proposed is that the AP activation of the left wall is not early enough to affect the beginning of the QRS, yet reduces the total left ventricular activation time sufficiently to allow the terminal part of right ventricular activation to be unopposed, thus producing the secondary r' wave observed. Lim et al.¹⁶ also observed the similar result in a patient with left AP. The results of these reports are in agreement with our data.

In the analysis of activation, sequence of heart and direction (including the magnitude, direction of rotation) of instantaneous vector, the VCG has been as advanced as a diagnostic tool, which is superior to the ECG.^{17,18} It is more convenient for VCG to analyze the initial and terminal QRS vector of preexcitation syndrome in comparison to ECG, which is helpful for the diagnosis of atypical preexcitation syndrome (with no evident delta

wave or shortened PR interval) and localization of AP.

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