

R-wave peak time at DII: A new criterion for differentiating between wide complex QRS tachycardias

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BACKGROUND Differential diagnosis of wide QRS complex tachycardias using the 12-lead ECG may be difficult in many clinical settings.

OBJECTIVE The purpose of this study was to determine the value of ECG lead II, specifically, the duration at its beginning, defined as R-wave peak time (RWPT), in differentiating ventricular tachycardia (VT) from supraventricular tachycardia (SVT) in patients with wide QRS complex tachycardia.

METHODS Two hundred eighteen ECGs showing wide QRS complex tachycardias were evaluated. Two cardiologists blinded to the diagnosis measured RWPT duration at lead II (from the isoelectric line to the point of first change in polarity), and results between VT and SVT were compared, with the findings of electrophysiologic study used as the gold standard.

RESULTS One hundred sixty-three VTs had a significantly longer RWPT at DII (76.7 ± 21.7 ms vs 26.8 ± 9.5 ms in 55 SVT, $P = .00001$). Receiver operating characteristic curve identified RWPT ≥ 50 ms at lead II as having greater specificity and sensitivity in

discriminating VT from SVT. Area under the curve was 0.97 (95% confidence interval 0.95–0.99), positive likelihood ratio was 34.8, and kappa coefficient (κ) was 0.86. Bivariate analysis identified higher age in VT patients (60.7 vs 50.1 years, $P \leq .01$) and wider QRS complex duration at lead II in VT patients (169.4 vs 128.3 ms, $P < .0001$). QRS width at DII was not superior to RWPT in diagnosing VT.

CONCLUSION RWPT ≥ 50 ms at DII is a simple and highly sensitive criterion that discriminates VT from SVT in patients with wide QRS complex tachycardia.

KEYWORDS Differential diagnosis; Electrocardiography; Sensitivity; Specificity; Supraventricular tachycardia; Ventricular tachycardia

ABBREVIATIONS ROC = receiver operating characteristic; RWPT = R-wave peak time; SVT = supraventricular tachycardia; VT = ventricular tachycardia

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Introduction

Wide QRS complex tachycardias (QRS ≥ 120 ms) may have several causes, including ventricular tachycardia (VT), supraventricular tachycardia (SVT), preexcited tachycardia, or a pacemaker rhythm.^{1–3} VT usually carries a worse prognosis, particularly in the presence of structural heart disease.⁴ Recognizing the origin of wide QRS complex tachycardias is of significant importance because it determines the type of treatment that should be initiated in a timely fashion. Several ECG criteria for determining whether a wide QRS complex tachycardia is of supraventricular or ventricular origin have been proposed; however, most of these criteria lack specificity and are difficult to use.^{1,3,5}

VT is the most common cause of wide and regular QRS complex tachycardias,^{2,6} and despite the history of ECG and

cardiac electrophysiology, few criteria are based on the duration of ventricular depolarization.^{7–11} The depolarization impulse travels through the normal His–Purkinje system faster than in the contractile myocardium and may be one reason why initiation of ventricular depolarization in VT is longer than normal.¹² The duration of the initial inscription of the QRS complex at lead II as a discriminator between VT and SVT has not been systematically used. We measured R-wave peak time (RWPT) at lead II to determine whether this simple criterion could be useful in discriminating between VT and SVT in a series of subjects who presented with wide QRS complex tachycardia, with electrophysiologic study as the gold standard diagnosis. Expert consensus recommended use of RWPT rather than “intrinsic deflection” for defining the interval from onset of QRS to peak of the R,¹³ and we used RWPT independent of whether it was positive or negative.

Methods

Two cardiologists expert in analyzing wide QRS complex tachycardias evaluated 218 ECGs recorded from the same

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number of patients who had undergone electrophysiologic study for different reasons (i.e., ischaemic VT or accessory pathway catheter ablation) between June 2003 and January 2008. We analyzed RWPT at lead II, defined as QRS duration from initiation of depolarization until the first change of the polarity, independent of whether the QRS deflection was positive or negative. Two blinded cardiologists independently analyzed the ECGs, and the results were compared. In cases of disagreement, the two cardiologists reviewed the ECGs and came to a joint agreement. The electrophysiologic study findings were used as the gold standard for defining VT and SVT.

Statistical analysis

Data were collected in an Excel database. Demographic, clinical, and ECG characteristics were collected. RWPT measured at lead II was collected for each researcher. Mean and standard deviation were calculated for continuous variables and analyzed using Student's t-test. Proportions were reported and analyzed using Chi-square analysis. Tables of contingency to evaluate sensitivity and specificity of the cutoff point for RWPT measured at lead II were calculated after the receiver operating characteristic (ROC) curve was obtained. The area under the curve and interobserver agreement with kappa coefficient (κ) also were determined. The likelihood ratio was calculated per Landis and Koch.¹⁴ Analysis was performed using the Stata software (version 8.0, Statacorp, LP, College Station, TX, USA).

Results

Patients

The study included 218 ECGs (one ECG per patient) showing wide and regular QRS complex tachycardias recorded between June 2003 and January 2008. Demographic and ECG data are summarized in Table 1. In total, 173 (79%) men and 45 women were included in the analysis. Mean patient age was 58 ± 16 years (range 18–80 years). There was a significant difference in age between VT and SVT patients (60.7 ± 13.4 years vs 50.1 ± 20.2 years, $P =$

Table 1 Summary of main study results

	Total	VT	SVT	P value
No. patients	218	163	55	
Male (%)	79	85	56	.001
Age (years)	58 ± 16	60 ± 13	50 ± 20	.0001
Mean heart rate (bpm)	—	162	172	.2
Mean QRS duration at DII (ms)	—	169	128	.001
R-wave peak time at DII (ms)	—	76.7 ± 21	26.8 ± 9.5	.00001

Values are given mean \pm SD unless otherwise indicated.

SVT = supraventricular tachycardia; VT = ventricular tachycardia.

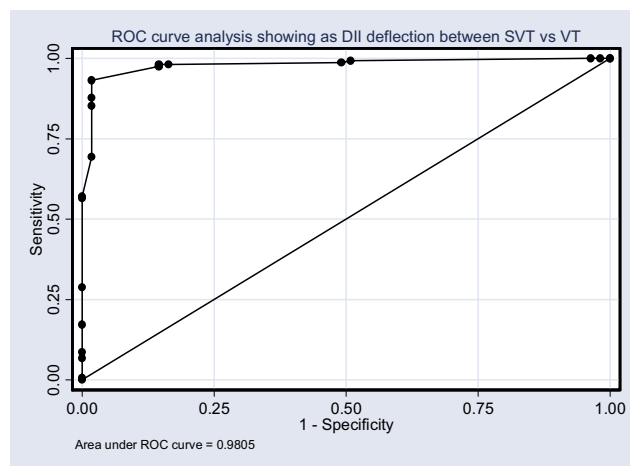


Figure 1 Receiver operating characteristic (ROC) curve showing sensitivity and 1-specificity of R-wave peak time value ≥ 50 ms. SVT = supraventricular tachycardia; VT = ventricular tachycardia.

.0001). The proportion of men with VT was significantly greater than men with SVT (84.8% vs 56.4%, $P = .001$).

ECG characteristics

All of the ECGs (163 VT, 55 SVT) recorded during electrophysiologic study showed wide QRS complex (≥ 120 ms) tachycardias. RWPT measured at lead II in patients with VT was significantly wider than in patients with SVT (76.7 ± 21.7 ms vs 26.8 ± 9.5 ms, $P = .00001$). QRS duration at lead II was significantly wider in VT patients than in SVT patients (169.4 ± 40.7 ms vs 128.3 ± 28.1 ms, $P < .01$). No difference in heart rate was noted between VT and SVT patients (162.1 bpm vs 172.6 bpm, $P = .2$). No difference in RS duration at lead II, when present, was noted between VT and SVT patients (83.6 ms vs 69.7 ms, $P = .069$).

ROC curve

The ROC curve determined that RWPT ≥ 50 ms measured at lead II was optimal for differentiating VT from SVT. Maximal sensitivity was 0.93, specificity 0.99, and area under the curve 0.97 (Figure 1). RWPT cutoff value ≥ 50 ms was associated with a positive predictive value of 0.98 and negative predictive value of 0.93. The positive likelihood ratio was 51.3, and the negative likelihood ratio was 0.06. Interobserver agreement was $\kappa = 0.86$. QRS width at DII was measured and compared to electrophysiologic study findings (gold standard). The best cutpoint for identifying VT was QRS ≥ 130 ms, which had sensitivity of 0.83, specificity 0.58, positive likelihood ratio 2.03, and negative likelihood ratio 0.28. Figure 2 shows the ROC curve for the optimal QRS width for identifying VT: cutoff ≥ 130 ms. Tables 2 and 3 summarize the findings for RWPT ≥ 50 ms and QRS width ≥ 130 ms, respectively. RWPT was superior to width QRS in identifying VT. Figure 3 shows a box plot graph comparing RWPT between patients with VT and those with SVT. For RWPT, sensitivity increased to 1

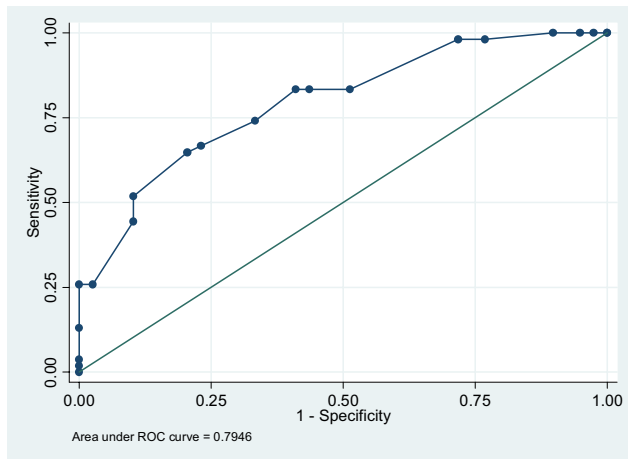


Figure 2 Receiver operating characteristic (ROC) curve showing sensitivity and 1-specificity of QRS width ≥ 130 ms at DII.

when six fascicular VTs (which have some characteristics like SVT) and one SVT due to preexcited antidromic tachycardia in a patient with Ebstein anomaly (very wide QRS) were excluded. Figure 4A shows a typical 12-lead ECG corresponding to a wide QRS complex tachycardia due to VT. An enlargement of the lead II recording (Figure 4B) shows RWPT ≥ 50 ms (80 ms). Figure 5A shows a wide complex QRS tachycardia secondary to SVT. An enlargement of the DII recording (Figure 5B) shows RWPT < 50 ms (30 ms). Figure 6A shows a VT with negative deflections in the inferior leads. Figure 5B shows “RWPT” at DII ≥ 50 ms (60 ms = VT).

Discussion

We measured the first deflection of lead II (RWPT) during a regular wide complex tachycardia on 12-lead ECG with the objective of evaluating its utility in differentiating VT from SVT. We compared those results, in blinded fashion, using the diagnosis made at electrophysiologic study as the gold standard. RWPT, defined as the QRS duration from the isoelectric line to its first deflection, was significantly wider in patients with VT (76.7 ± 21.7 ms) than in those with SVT (26.8 ± 9.5 ms, $P < .01$); RWPT ≥ 50 ms at DII had a positive predictive value of 0.93 and negative predictive value of 0.99 for identifying VT.

Table 2 Table of contingency using R-wave peak time ≥ 50 ms at DII

Test	Value
Sensitivity	93.2 (67.3–93.2)
Specificity	99.3 (74.1–99.8)
Positive predictive value	98.2 (89–99.8)
Negative predictive value	93.3 (87.9–96.4)
Area under the curve	0.98 (0.95–0.99)
Positive likelihood ratio	51.3
Negative likelihood ratio	0.06
Interobserver agreement	$\kappa = 0.86$

Table 3 Table of contingency using QRS width ≥ 130 ms at DII

Test	Value
Sensitivity	83.33
Specificity	58.97
Correctly classified	73.12%
Positive likelihood ratio	2.0312
Negative likelihood ratio	0.2826
Area under the curve	0.7946

To the best of our knowledge, this is the first study analyzing RWPT at lead II for differential diagnosis of patients presenting with wide QRS complex tachycardias. Differentiating between SVT and VT in this setting has important clinical and therapeutic implications, and ECG is of paramount importance in this aim. Although ECG deductive analysis has been the cornerstone for differential diagnosis of wide QRS complex tachycardias, few criteria (morphologic, clinical, logical, duration) have been introduced and validated. At this time, few studies use QRS complex duration criteria^{7–11} to differentiate wide QRS complex tachycardias; our study is one of the few that used duration criteria. We did not compare our results with other previous criteria (i.e., criteria of Brugada et al) because our gold standard was electrophysiologic study. We chose lead II because it is a lead easy to obtain and it almost always is present on ECG rhythm strips recorded in different settings (e.g., ECG monitoring in emergency rooms and intensive care units). We also chose lead II based on personal observations previously reported.¹⁵

The underlying basis of our study finding probably is related to the different conduction velocities that occur in SVTs (using the fast conducting His–Purkinje system) compared to VTs (using the myocardium itself). The impulse conducts faster longitudinally over ventricular muscle and the His–Purkinje system, that is, the terminals have more gap junctions, which conduct the velocity faster along the fibers than in the cross direction, which contains much

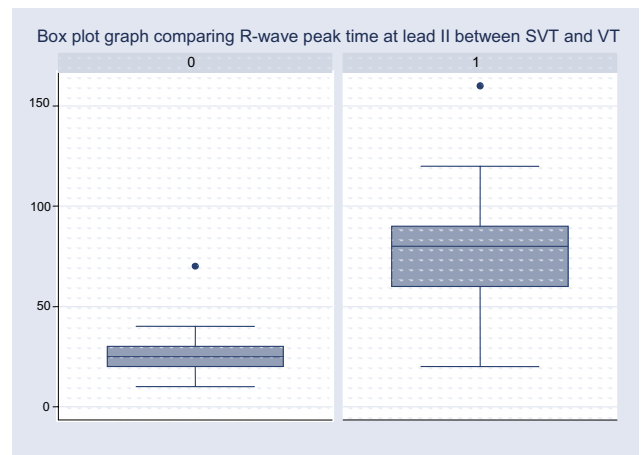


Figure 3 Box plot comparing R-wave peak time at lead II for ventricular tachycardia (VT, right panel) and supraventricular tachycardia (SVT, left panel).

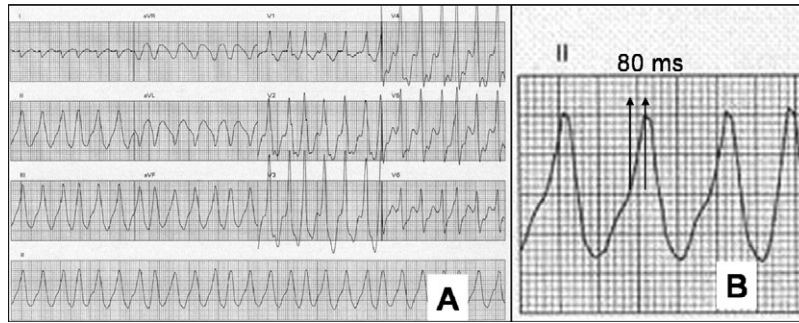


Figure 4 A: Twelve-lead ECG from a patient with ventricular tachycardia. B: Magnified lead II from panel A. R-wave peak time (RWPT) was ≥ 50 ms (RWPT duration 80 ms).

fewer gap junctions.¹⁶ Conduction velocity in the ventricles is known to be faster in the His–Purkinje system (2.5 m/s) than in contractile ventricular myocardium (0.4–0.9 m/s),¹⁷ depending on the direction of conduction. Clerc¹⁸ found a ratio of 3:1 for longitudinal to transverse conduction velocity of the ventricular impulse. The difference in conduction velocity between SVT using the normal His–Purkinje system and VT using the muscle itself could be the basis for understanding the large difference between the two arrhythmias. We believe that the advantage of this new criterion, the RWPT at DII, could be one more tool for easily differentiating wide QRS complex tachycardias in the emergency room or intensive care unit, or in daily practice. A limitation of this study may be related to the difficulty in defining the initiation and peak of ventricular complexes. A disagree-

ment on the measured duration of RWPT at lead II was seen in only 3.66 % (8/218) of ECGs. The reasons for the discrepancy were the lack of clear onset of QRS at lead II and an unclear peak of the deflection. Our new criterion is simple, reproducible, and highly sensitive and specific for differentiation of wide complex QRS tachycardias. Further prospective studies comparing our criteria are needed to determine the validity of this criterion in distinguishing between VT and SVT.

Conclusion

RWPT measured at DII is a simple and helpful tool for differentiating VT from SVT. This exploratory study documented that RWPT ≥ 50 ms measured at lead II had sensitivity of 93%, specificity of 99%, and positive predic-

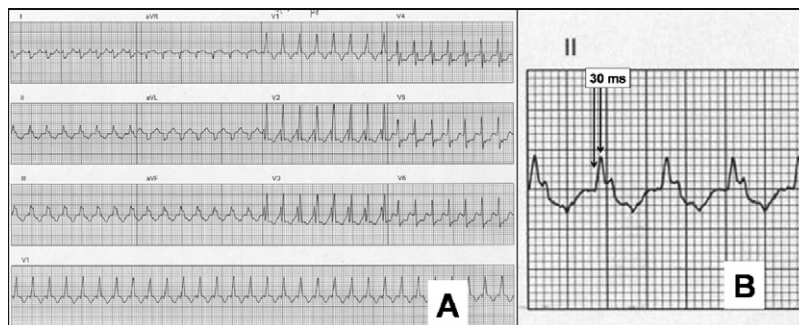


Figure 5 A: Twelve lead ECG from a patient with supraventricular tachycardia and right bundle branch block morphology. B: Magnified lead II from panel A. R-wave peak time (RWPT) was < 50 ms (RWPT duration 30 ms).

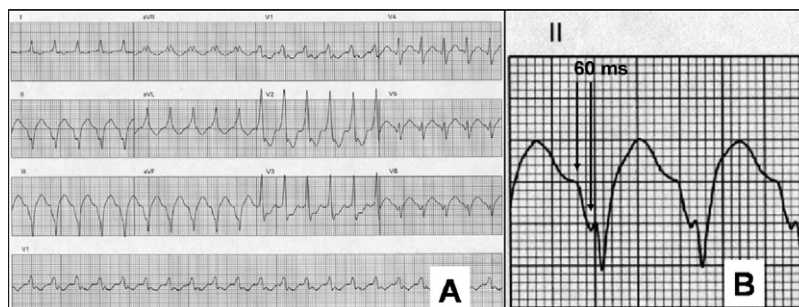


Figure 6 A: Twelve-lead ECG from a patient with ventricular tachycardia and negative deflection in inferior leads. B: Amplified DII shows negative “R-wave” peak time ≥ 50 ms (RWPT duration 60 ms).

tive value of 98%. This simple approach needs to be validated in other studies and compared with other algorithms in order to confirm our findings.

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