The JT Interval as a Depolarization Independent Measurement of Repolarization: Lessons from Catheter Ablation of the Wolff-Parkinson-White Syndrome

MUBADDA A. SALIM, CHRISTOPHER L. CASE,* and PAUL C. GILLETTE*

From the University of Tennessee, Memphis, Tennessee; and the *Medical University of South Carolina, Charleston, South Carolina

SALIM, M.A., ET AL.: The JT Interval as a Depolarization Independent Measurement of Repolarization: Lessons from Catheter Ablation of the Wolff-Parkinson-White Syndrome. *In patients with Wolff-Parkinson-White syndrome (WPW), preexcitation precludes accurate assessment of the ventricular repolarization by the QT_c. In patients with long QT syndrome, it has been demonstrated that the JT_c does not change when depolarization abnormalities develop. We hypothesized that this phenomenon should also be applicable to WPW patients. To test this, we assessed the surface ECG of 29 patients (16 males, 13 females) with WPW pre- and postablation. The QRS, QT, and JT intervals were measured pre- and postablation at 50 mm/s paper speed in leads II and V_2. QT_c and JT_c were calculated according to Bazett's formula. The average age was 12.8 ± 4.9 years (range 1.5–21). All patients had no residual preexcitation on postablation ECG. Early and late follow-up ECGs were obtained at 32 ± 34 days and 388 ± 197 days postablation, respectively. Both the QRS and the QT_c intervals shortened significantly on the postablation versus preablation ECGs (QRS: 115 ± 23 ms vs 89 ± 15 ms, respectively; $P < 0.0001$), (QT_c: 454 ± 26 vs 423 ± 23, respectively; $P < 0.0001$). The preablation JT_c interval did not change, postablation (319 ± 21 vs 323 ± 23, respectively; $P > 0.2$). Also, the JT_c interval did not change between early and late follow-up, postablation. JT_c is an independent measure of repolarization, not related to depolarization. JT_c may be a useful tool in assessing repolarization in patients with WPW and other depolarization abnormalities. (PACE 1995; 18:2158–2162)*

JT interval, QT interval, ventricular repolarization, preexcitation

Introduction

Depolarization abnormalities in patients with Wolff-Parkinson-White syndrome (WPW) and other causes of wide QRS complexes may preclude accurate measurement of repolarization as assessed by the QT and corrected QT (QT_c) intervals. The JT and corrected JT (JT_c) intervals represent the specific ventricular repolarization time, and has been shown, in patients with long QT syndrome, to be independent of the QRS duration.[1] To further explore this phenomenon, we hypothesized that in patients with WPW (i.e., wide complex QRS), the JT interval corrected to heart rate will not change following catheter ablation of accessory pathways and disappearance of preexcitation. As such, in the presence of abnormalities of ventricular activation, the JT_c, rather than the QT_c interval, may be a more reliable measure of repolarization.

Methods

We retrospectively reviewed 29 patients with WPW who had successful radiofrequency ablation of their accessory pathways. Electrocardiograms in the resting supine position, before and after ablation, were evaluated. Only patients with visible preexcitation on surface electrocardiograms were included in this study. All measurements were made manually (Fig. 1), with the aid of a caliper, from limb lead II electrocardiograms, and chest lead V_2 at 50 mm/s paper speed at 20 mm/1 mV

Address for reprints: Christopher L. Case, M.D., South Carolina Children's Heart Center, 171 Ashley Ave., Charleston, SC 29425-0680. Fax: (803) 792-3284.

Received June 20, 1994; revision October 28, 1994; accepted November 21, 1994.

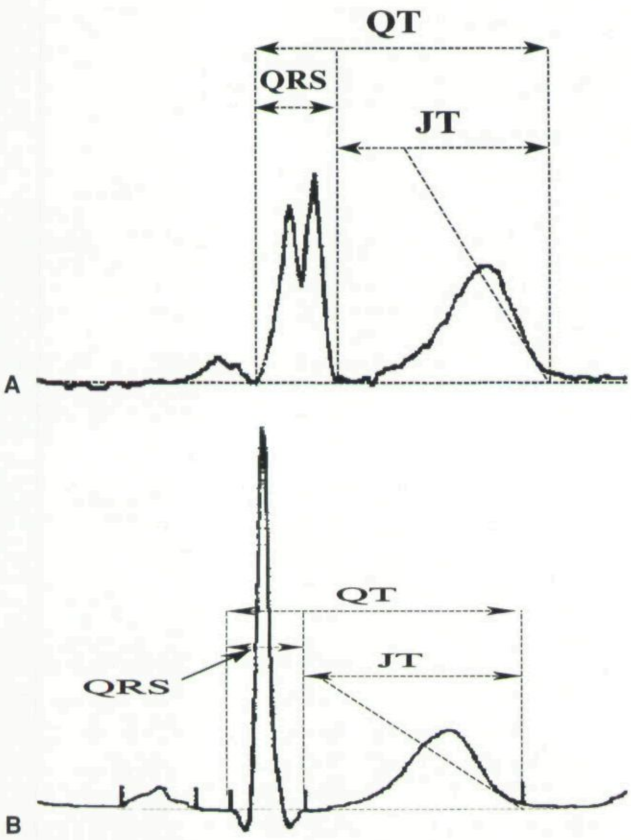

Figure 1. *The measurement of the QRS, QT, and JT intervals in lead II in a patient with Wolff-Parkinson-White syndrome. Panel A: Measurements prior to ablation. Panel B: Measurements after ablation.*

(Marquette Electronics, Inc., Jupiter, FL, USA) at 100-Hz filtration (program 107A, 12SLtm v78). Lead II was chosen as recommended by Moss et al.[2] in the international study of patients with long QT syndrome. Also, the T wave in lead II is a single large wave without a large U wave,[3] making it easier to determine its endpoint. Lead V_2 was chosen because it has the largest T wave amplitude and the longest QT interval.[4] The QRS complex duration was determined between its initial depolarization (the beginning of the delta wave prior to ablation) and the J point. When the landmarks at the end of the QRS complex were distinct, the J point was determined as the beginning of the isoelectric S-T segment. If, on the other hand, the landmarks were not distinct, the J point was the intercept point between a tangent to the descending part of the R wave or the ascending part of the S wave and the isoelectric line drawn through the S-T segment.[5] The end of the T wave was the intersection between a tangent to the downslope of the T wave and the isoelectric line.[4] Measurements included the PR, the QRS, the QT, and the JT intervals. The RR interval was averaged over 5 consecutive beats. Bazett's formula was used to correct for heart rate, whereas: $QT_c = QT/\sqrt{RR}$, and $JT_c = JT/\sqrt{RR}$.

Statistical analyses were performed on StatView 4.0 software (Brainpower, Inc., Calabasas, CA, USA). Paired and unpaired Student's *t*-test were used where applicable. Correlation was determined by regression analysis. A P value < 0.05 was considered significant.

Results

The study population consisted of 16 males and 13 females. The mean age at ablation was 12.8 ± 4.9 years (range 1.5–21). All patients had at least one electrocardiogram prior to ablation that showed obvious ventricular preexcitation. Early follow-up electrocardiograms postablation were obtained after a mean follow-up duration of 32 ± 34 days (range 1–165, median 38). Because of the retrospective nature of the study, the first electrocardiogram available for analysis was considered as the early follow-up electrocardiogram.

There were ten electrocardiograms obtained in the first 2 days postablation. Long-term follow-up electrocardiograms were available for 12 patients, 388 ± 197 days (range 98–794) postablation. Ablation was considered successful in all patients, by electrophysiological testing, immediately after the procedure. In addition, no postablation electrocardiogram showed any residual preexcitation. Table I summarizes the values of the measurements obtained. When contrasting the pre- and early postablation values, as expected the QRS, PR, and QT_c were significantly different in both leads. However, the JT_c pre- and postablation were comparable, suggesting a similar repolarization time intervals. Late follow-up of the postablation patients have shown no significant change in the JT_c when compared to either the preablation or the early postablation values. The QRS complex contribution to the QT interval, in lead II, was 29% ± 5% preablation, compared to 24% ± 3% postablation ($P < 0.0001$). There was a significant cor-

Table I.

Summary of the Electrocardiographic Intervals Pre- and Post-Ablation

	Pre-Ablation (ms)		Post-Ablation (ms) Early		Post-Ablation (ms) Late		P Values	
	Lead II	Lead V_2	Lead II	Lead V_2	Lead II	Lead V_2	Lead II	Lead V_2
QRS	115 ± 23	118 ± 23	89 ± 15	91 ± 14	86 ± 6	86 ± 10	< 0.0001	< 0.0001
PR	102 ± 23	99 ± 24	134 ± 18	136 ± 17	139 ± 14	138 ± 17	< 0.0001	< 0.0001
RR	768 ± 159		785 ± 170		800 ± 140			
QT_c	454 ± 26	442 ± 30	423 ± 23	410 ± 35	421 ± 18	408 ± 25	< 0.0001	< 0.0003
QT_c (male)	451 ± 28	438 ± 24	418 ± 26	410 ± 34	425 ± 27	408 ± 25	< 0.0009	< 0.007
QT_c (female)	459 ± 25	449 ± 36	428 ± 20	409 ± 37	420 ± 20	409 ± 30	< 0.001	< 0.02
JT_c	319 ± 21	315 ± 27	323 ± 23	312 ± 25	324 ± 16	313 ± 26	0.23	0.59
JT_c (male)	311 ± 20	306 ± 26	317 ± 15	314 ± 19	327 ± 26	312 ± 29	0.1	0.20
JT_c (female)	330 ± 18	327 ± 24	329 ± 20	311 ± 31	327 ± 17	316 ± 24	0.79	0.14

The comparison is between pre-ablation and post-ablation values. The early and late post-ablation values were not different.

relation between the QT and QRS duration before ($r = 0.55$; $P < 0.002$) and after ($r = 0.45$; $P < 0.02$) ablation. The JT interval, on the other hand, did not correlate with either pre- or postablation QRS duration. Preablation, the QT_c values were similar between males and females, while the JT_c values of the male patients were significantly shorter than the female values ($P < 0.003$). Postablation, the JT_c and QT_c values for male patients tended to be shorter than those for female patients. All patients had normal JT index according to Zhau et al.[6] and normal JT_c value according to Zareba et al.,[1] both pre- and postablation. The QT_c values were normal in all patients except one. This patient had complete right bundle branch block and a prolonged QT_c of 466 ms, however, his JT_c was normal (303 ms).

Preablation, there was no significant difference in the JT_c or the QT_c values between the two leads used. Postablation, both the QT_c and the JT_c values were shorter in lead V_2 than lead II (QT_c: $P < 0.04$; JT_c: $P < 0.006$).

Discussion

The measurement of the QT and the rate corrected QT_c is a cornerstone in the diagnosis of the congenital long QT syndrome.[7] Acquired prolongation of the QT_c has been associated with increased mortality after myocardial infarction,[8] and in patients with chronic ischemic heart disease.[9] In the presence of intraventricular conduction abnormalities, the prolongation of the QRS produces a prolonged QT interval and as a result, a prolonged QT_c. Das[5] found a significantly longer QT_c interval, in patients with left axis deviation, right bundle branch block, and left bundle branch block, compared to normal controls. However, the JT interval and a value derived by subtracting the QRS complex duration from the QT_c interval (QT_c − QRS), were similar between patients and controls. In patients with dilated cardiomyopathy the QT_c was significantly longer in nonsurvivors compared to survivors.[10] The JT and the QT_c-QRS intervals of patients who died of congestive heart failure were similar to those of survivors. However, patients with dilated cardiomyopathy who died suddenly had significantly longer JT and QT_c-QRS intervals than both survivors and those who died of congestive heart failure. We elected to calculate the JT_c interval according to the method described by Zareba et al.,[1] because it allowed us to compare the values of the JT_c interval of our patient population to their reported normative data.

Our data show that the QT_c in patients with preexcitation may be an inaccurate measure of ventricular repolarization because of the inclusion of an abnormally wide QRS complex in the calculation. The QT interval represents both ventricular depolarization and repolarization and, as such, is dependent on the QRS duration. The JT interval reflects the repolarization in the basal portion of the right and left ventricles, and is independent of the ventricular depolarization.[6] The patients with WPW represent a unique population in that they have normal cardiac anatomy, and with the ablation of the accessory pathway regain normal cardiac conduction. Yet, in this group the JT_c values did not change while the QT_c changed significantly, and on late follow-up there was no significant change from the preablation values. This is similar to data reported in long QT syndrome patients who had no change in their JT_c after developing a wide QRS because of bundle branch block or ventricular pacing.[1]

The association between prolonged JT and JT_c intervals in patients with the long QT syndrome, and those with cardiomyopathy and sudden death, may provide a valuable tool in the evaluation of repolarization abnormalities in patients with depolarization abnormalities. In the WPW patient population, the JT_c proves the presence of normal ventricular repolarization and may be helpful in their management especially before ablation. In the presence of a prolonged JT_c interval prior to ablation, an antiarrhythmic drug that is known to prolong repolarization could, theoretically, be detrimental and should be avoided if possible. Our data as well as the works of others may provide further support to those calling for the substitution of the JT_c interval for the QT_c interval in the evaluation of ventricular repolarization.[11,12]

By measuring the QT and JT intervals from two different leads we were able to better isolate any influence a flat delta wave may have had on the values obtained. There were differences between the leads, as the QT_c and the JT_c values in lead V_2 were shorter postablation than those of lead II. However, within the same lead the JT_c was consistantly similar and the QT_c shortened after ablation.

Our study did not attempt to evaluate the qualitative changes of the T wave morphology observed in the early postablation period.[13,14] previous reports described these changes in the T wave vector without evaluating the changes in the repolarization duration. Moreover, these changes in the T wave vector were observed in the first few days following ablation. The electrocardiograms evaluated, in our study, were obtained in most of the patients beyond the initial follow-up period.

Theoretically, further support for this study could be derived from the measurement of the QT and the JT intervals with and without right ventricular pacing, or at different sites within the ventricle during an electrophysiological study. However, whether repolarization parameters measured during electrophysiological testing are similar to those on standard electrocardiogram needs further study before we can use it. The different response characteristics of each recording instrument may produce large variations in the values obtained. It has been shown that the QT interval measured from a 24-hour continuous electrocardiographic monitoring is different from that obtained on the standard electrocardiogram.[3] Comparing these values may not be accurate.

In summary, these data suggest that the use of the JT_c interval is a more specific measure of repolarization and should be considered as a valid substitute to the QT_c interval, especially in the presence of abnormal ventricular activation.

Acknowledgments: Our thanks to Dr. Joel B. Cochran, Christine A. McKay, and Fred Varney, Jr., for their assistance.

References

1. Zareba W, Moss AJ, and the LQTS Study Group. Criteria for delayed repolarization in patients with wide QRS complex. (abstract) J Am Coll Cardiol 1994; 23:37A.
2. Moss AJ, Schwartz PJ, Crampton RS, et al. The long QT syndrome: A prospective international study. Circulation 1985; 71:17–21.
3. Garson A Jr. How to measure the QT interval—What is normal? Am J Cardiol 1993; 72:14B-16B.
4. Funck-Brentano C, Jaillon P. Rate-corrected QT interval: Techniques and limitations. Am J Cardiol 1993; 72:17B-22B.
5. Das G. QT interval and repolarization time in patients with intraventricular conduction delay. J Electrocardiol 1990; 23:49–52.
6. Zhau SH, Wong S, Rautaharju PM, et al. Should the JT rather than the QT interval be used to detect prolongation of ventricular repolarization? J Electrocardiol 1992; 25(Suppl.):131–136.

7. Schwartz PJ, Moss AJ, Vincent GM, et al. Diagnostic criteria for the long QT syndrome. An update. Circulation 1993; 88:782–784.
8. Wheelan K, Mukharji J, Rude RE, et al. Sudden death and its relation to QT-interval prolongation after acute myocardial infarction: Two year follow-up study. Am J Cardiol 1986; 57:745–750.
9. Puddu PE, Bourassa MG. Prediction of sudden death from QT_c interval prolongation in patients with chronic ischemic heart disease. J Electrocardiol 1986; 19:203–211.
10. Cianfrocca C, Pelliccia F, Nigri A, et al. Resting and ambulatory ECG predictors of mode of death in dilated cardiomyopathy. J Electrocardiol 1992; 25: 295–303.
11. Spodick DH. Reduction of QT-interval imprecision and variance by measuring the JT interval. Am J Cardiol 1992; 70:103.
12. Pelliccia F, Critelli G. Evidence of prognostic role of the JT interval. Am J Cardiol 1993; 71:758.
13. Kalbfleisch SJ, Sousa J, El-Atassi R, et al. Repolarization abnormalities after catheter ablation of accessory atrioventricular connections with radiofrequency current. J Am Coll Cardiol 1991; 18: 1761–1766.
14. Poole JE, Bardy GH. Further evidence supporting the concept of T-wave memory: Observations in patients having undergone high-energy direct current catheter ablation of the Wolff-Parkinson-White syndrome. Eur Heart J 1992; 18:801–807.