PQRST isoarea maps from patients with the Wolff-Parkinson-White syndrome: an index for global alterations of ventricular repolarization

REGINALD NADEAU, M.D., F.R.C.P.(C.), ALEXANDRE ACKAOUI, M.Sc., CONRADO GIORGI, M.D., M.Sc., PIERRE SAVARD, Ph.D., MOHAMMAD SHENASA, M.D., Ph.D., AND PIERRE PAGÉ, M.D., F.R.C.S.(C.)

ABSTRACT Isoarea maps during the PQRST sequence were computed in 22 healthy subjects and 48 patients with Wolff-Parkinson-White (WPW) syndrome. Thirty-eight patients with WPW were on no medication and 10 were treated with class I, II, or III antiarrhythmic drugs. Seventeen isoarea maps were recorded before and 17 were recorded after accessory pathway ablation. One patient had intermittent preexcitation. Body surface maps from all healthy subjects were similar, although the magnitudes of the maxima and minima showed significant variability. In all patients with WPW who were on no medication and in those on class I and II agents, PQRST maps were normal. Two patients taking amiodarone had abnormal PQRST maps, as did patients early after surgery. In the patient with intermittent preexcitation, PQRST maps were very similar during normal and preexcited beats. In conclusion, our results support the theory that the PQRST time integral reflects intrinsic recovery properties of the heart and is independent of the activation sequence.


WILSON et al.1 reported in 1934 evidence that the algebraic sum of the QRST area, called the ventricular gradient, is independent of the activation sequence and reflects intrinsic repolarization changes. However, controversies regarding this concept arose in later studies. Some authors denied its validity because of the great variability of the ventricular gradient.2, 3 whereas others provided theoretical4, 5 and experimental evidence for its relative independence from the activation sequence and its relationship to ventricular recovery properties.6–10

In 1977, Abildskov et al.11 introduced body surface mapping of the QRST time integral and emphasized the usefulness of this approach in detecting vulnerability to arrhythmias. More recently, such body surface maps have been investigated in healthy subjects by Montague et al.,12 who concluded that the thoracic distribution of the ventricular gradient was relatively consistent in all healthy subjects, but that there was significant variability in the magnitudes of the maxima and minima even in sequential recordings in the same subjects.

In the present study, body surface mapping of the PQRST time integral was used to investigate the repolarization alterations in patients with the Wolff-Parkinson-White (WPW) syndrome. Our purpose was to determine whether the modifications of the ST-T waveforms are secondary to alterations in the activation sequence, or result from modifications in the ventricular recovery process. These patients represent a potentially useful model for studying the effects of different activation sequences on the ventricular gradient. Indeed, preexcitation through an accessory pathway should not produce any electrotonic interactions such as those induced by pacing electrodes, which may alter recovery properties.10, 13
Methods
Study group. The group of healthy subjects consisted of 14 men and eight women between 18 and 44 years old. None had an history of cardiac or pulmonary disease and all had normal 12-lead electrocardiograms, M mode echocardiograms, and chest x-rays. The WPW group consisted of 48 patients between 18 and 60 years old. Thirty-eight patients were on no medication, and 15 of these underwent study before and after surgical interruption of their accessory pathway by cryoablation; one patient underwent study during intermittent preexcitation. Ten patients (two of whom later had surgical interruption of the Kent bundle) were receiving antiarrhythmic agents: four received a class I agent (three quinidine, one propafenone), one patient received a class II agent alone, two received a class III agent (amiodarone), and three received both class I and II agents. None of these patients had a clinical history of other cardiac or pulmonary disease, except for five patients who had a slight degree of mitral valve prolapse at the bidimensional echocardiographic examination. None had evidence of electrolyte disorders and all had normal chest x-rays.

Data acquisition and processing. Our body surface potential mapping procedure has already been described elsewhere. Briefly, electrocardiograms were recorded in patients in the supine position with 63 unipolar leads referenced to the Wilson central terminal. Normal sinus rhythm beats were averaged over a 52 sec period. Correction of the baseline drift was performed by subtracting from the signals a line joining the preceding and following TP intervals. For each of the 63 averaged signals, the time integral between the beginning of the P wave and the offset of the T wave was computed. The P wave was included in the integration period to reduce the effects of the atrial repolarization that is present during the QRS complex and ST segment.

The results are presented as body surface maps in which contour lines join points having either the same net area under the PQRST sequence (PQRST maps), or the same potential at a given instant (isopotential maps). These maps are displayed in a rectangular format corresponding to unrolling the thorax after slicing down the subject’s right side, with the left side representing the front of the torso and the right one the back. The heavier contour line represents the zero value. The most negative and most positive values are indicated by minus and plus signs, respectively. The positive areas on both the PQRST and the isopotential maps are crosshatched.

Results
In healthy subjects, PQRST maps of both men and women demonstrated similar dipolar patterns, with positive values distributed mainly over the left chest and negative values over the right chest. The maximum was consistently located over the precordium, whereas the minimum was located superiorly, either over the posterior chest (six subjects), or over the right anterior chest (16 subjects). These two normal variations are illustrated in figure 1, A and B, respectively. Also, the values of the maximum (table 1) were slightly higher for men than for women (p < .1).

For patients with WPW, isopotential maps during the delta wave and ST segment were first classified into seven categories corresponding to the location of the preexcitation site. We found a wide range of estimated accessory pathway locations: anteroseptal in five patients, right lateral in two, right posterior in eight, posteroseptal in five, left posterior in two, left lateral in 19, and left anterior in seven patients. Despite these different preexcitation patterns, all patients with WPW who were not receiving antiarrhythmic medication had normal PQRST maps. This is illustrated in figure 2, which shows both isopotential and PQRST maps from two patients, one with an anteroseptal (panel A) and one with a left lateral (panel B) preexcitation site. Their isopotential maps are very different, but their PQRST maps show striking resemblances and are similar to normal ones. For patients with WPW on no medication (table 1), the maximum integral values were significantly higher for men than for women (p < .005), but

| TABLE 1 |
| PQRST magnitudes |

<table>
<thead>
<tr>
<th></th>
<th>Men</th>
<th></th>
<th>Women</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maxi</td>
<td>Minim</td>
<td></td>
<td>Maxi</td>
</tr>
<tr>
<td>Normal</td>
<td>14</td>
<td>91±36</td>
<td>-29±12</td>
<td>8</td>
</tr>
<tr>
<td>WPW, no drugs</td>
<td>14</td>
<td>121±34</td>
<td>-44±25</td>
<td>24</td>
</tr>
<tr>
<td>WPW, drugs</td>
<td>3</td>
<td>74±37</td>
<td>-29±10</td>
<td>7</td>
</tr>
</tbody>
</table>

Values are expressed in mV-msec; mean ± SD. Significant differences for the maximum were found between men and women with WPW (p < .005).
the maximum and minimum integral values were not significantly different from those of the normal group.

All the patients with WPW treated with class I and class II agents had normal PQRST maps, whereas the two patients treated with amiodarone had abnormal PQRST maps. Results from two patients with the same right posterior preexcitation pattern, one of whom was receiving a class II agent and the other amiodarone, are shown in figure 3, A and B, respectively. The PQRST map was normal in the first case and abnormal in the second. The patient treated with amiodarone subsequently underwent successful cryoablation of the accessory pathway and after 6 months without amiodarone had a normal PQRST map. No differences were found between drug-treated patients with WPW and healthy subjects with respect to maximum and minimum potential values (table 1).

All 17 patients who underwent cryoablation of the preexcitation pathway had normal PQRST maps in both preoperative and late postoperative states. Results for a typical patient are shown in figure 4: before surgery (panel A), the isopotential maps show a left anterior preexcitation pattern and the PQRST map is normal; 6 weeks after surgery (panel B), the PQRST map was different from the preoperative one, with a negative region covering most of the inferior torso. One

FIGURE 2. The isopolar PQRST maps from a patient with anteroseptal (A) and a patient with a left lateral (B) preexcitation pathway not receiving any antiarrhythmic agent. In both map types, the zero potential contour is indicated by a heavier trace and positive potential distributions are crosshatched. Iso-potential values are indicated in mV while isopolar values are in μV-sec.

FIGURE 3. The isopolar PQRST maps from two patients with a right posterior preexcitation pathway. A, Patient receiving a class II antiarrhythmic agent (propranolol); B, patient receiving a class III antiarrhythmic agent (amiodarone).
year after surgery (panel C), the PQRST map was again similar to the preoperative one.

We were able to record a spontaneously intermittent WPW pattern in a woman with a left lateral preexcitation pattern who was not receiving antiarrhythmic medication. The PQRST maps and the 12-lead electrocardiogram in both normal and preexcited states are shown in figure 5. The PQRST maps were very similar in both states, with the minimum displaced only slightly to the right, and the maximum being located at the same place but with the positive area distributed a little more to the right. The magnitudes of the maximum and minimum were different but fell within the normal range of variability.

**FIGURE 4.** The isoarea PQRS maps from a patient with a left anterior preexcitation pathway before surgery who did not receive an antiarrhythmic agent (A). Early postsurgical state is illustrated in B and late postsurgical state (1 year after surgery) is illustrated in C.

**FIGURE 5.** Isoarea PQRS maps and the 12-lead electrocardiogram from a patient with an intermittent left lateral preexcitation pathway not receiving any antiarrhythmic agent. Top, Preexcitation state; bottom, normal sinus rhythm.
Discussion

In our study, the PQRST maps of healthy men showed higher maximum values than those for women, in accordance with the observations of Montague et al., but on the whole, the morphology of the PQRST maps presented a consistent pattern that could be used to detect alterations in the distribution of ventricular recovery properties in patients with WPW.

One of the interesting findings of our study was that whatever the preexcitation site, the PQRST maps observed in all patients with WPW not receiving antiarrhythmic drugs and in those receiving class I and/or class II agents were similar to normal, both in morphology and magnitude. These findings thus support the hypothesis of the independence of the ventricular gradient and the activation sequence. The lack of drug effects of the PQRST maps is not surprising since these specific drugs have little effect on action potential duration.

Results in the two patients receiving amiodarone may be related to the marked prolongation of the action potential caused by this drug. However, a uniform lengthening of the action potential throughout the whole heart should not alter the PQRST time integral since it reflects the gradient of the areas under the action potential. Thus, the altered PQRST maps suggest that the effects of the drug may be inhomogeneously distributed in the heart.

With regard to the abnormal PQRST map recorded in the early postsurgical phase in one patient, since these abnormalities disappeared in later postsurgical recordings, they may be attributed to surgical pericarditis or alterations in the electrical properties of the torso.

In conclusion, we have found very little variation from the normal pattern in PQRST maps from patients with WPW with different preexcitation sites. These results show that the ST-T alterations are secondary to the altered activation sequence in these patients and confirm the relative independence of the ventricular gradient and activation sequences. The similarities of PQRST maps obtained during normal and preexcited beats in the patient with intermittent WPW and between the presurgery and postsurgery maps lends additional support to this concept.

References

1. Wilson FN, MacLeod AG, Barker PS, Johnston FD: The determination and the significance of the areas of the ventricular deflections of the electrocardiogram. Am Heart J 40:46, 1934
3. Ashman R, Byer E: The normal human ventricular gradient. II. Factors which affect its manifest area and its relation to the manifest area of the QRS complex. Am Heart J 25:36, 1943
PQRST isoarea maps from patients with the Wolff-Parkinson-White syndrome: an index for global alterations of ventricular repolarization.
R Nadeau, A Ackaoui, C Giorgi, P Savard, M Shenasa and P Pagé

Circulation. 1988;77:499-503
doi: 10.1161/01.CIR.77.3.499
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1988 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/77/3/499

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/