Elucidation of Prinzmetal’s Variant Form of Preexcitation

Anand Munsif, MBBS; Benjamin J. Scherlag, PhD; Ralph Lazzara, MD

Background In 1952, Prinzmetal induced preexcitation in the normal dog heart using subthreshold stimulation (SS) delivered to the right ventricle.

Methods and Results In 12 dogs we recorded ECG leads II, aVR, His (Hb) and proximal right bundle potentials with electrode catheters at the aortic root and a special electrode that was inserted through the right ventricular (RV) free wall. In 12 others, SS was delivered to the Hb area by a catheter placed under the septal leaflet of the tricuspid valve. During SS, the HV interval shortened from 35±4 milliseconds (mean±SD) to 19±7 milliseconds (P<.0001), but AH intervals were unchanged. The ECG showed delta waves with aberrant QRS complexes. Endocardial electrograms showed that the origin of activation in the preexcitation beats was localized to the muscle adjacent to the Hb or proximal right bundle. When vagal stimulation induced sudden AV block, no ventricular excitation was seen, confirming the subthreshold nature of the applied stimulation. By adjusting the levels of SS, latent forms of preexcitation could be induced, eg, early local septal muscle activation but no change in the ECG leads. Premature ventricular stimuli delivered to the RV apex or outflow tract could cause manifest preexcitation in the ECG leads or inhibit expression of latent preexcitation in endocardial recordings.

Conclusions SS delivered to the RV apex or Hb area causes ventricular preexcitation, as shown previously by Prinzmetal et al. SS delivered at the insertion sites of an accessory pathway may facilitate localization of such abnormal connections, particularly when preexcitation is concealed. (Circulation. 1994;89:2380-2389.)

Key Words • preexcitation • electrocardiography • His bundle

In 1952, Prinzmetal and his associates\(^1\) reported on the induction of preexcitation in the normal dog heart using various forms of subthreshold stimulation (SS) of the right ventricle. These workers claimed success in producing “all the known clinical types” of the Wolff-Parkinson-White (WPW) preexcitation syndrome, that is, isolated, continuous, alternating WPW beats and concertina effect by the use of subthreshold DC stimulation applied to the endocardial surface of the right ventricle at or near the apex. From these studies, the authors concluded that the atrial impulses in WPW complexes are transmitted to the ventricle in an abnormal manner by way of the normal conducting system.\(^1\) They attributed the “fundamental disorder... to a failure of a part of the [AV] node to delay the auricular impulse for the normal period of time before allowing passage to the ventricles” (Fig 1). This accelerated AV nodal conduction supposedly reached a particular portion of right ventricular (RV) muscle early enough to induce preexcitation.

With the advent of His bundle recordings, clinical electrophysiologists were able to discern that the WPW syndrome was mainly associated with anatomically distinct accessory AV connections that bypassed the AV node and His-Purkinje system.\(^2\)-\(^14\) The work of Prinzmetal et al\(^1\) has now been relegated to a category of variant or pseudo form of preexcitation.\(^15\)

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or six-ring electrode catheter with a 4-mm-long electrode at the tip was introduced into the right femoral vein and advanced to the apical area of the right ventricle (Fig 2). A plunge-wire electrode was inserted in the high right atrium near the sinus node for pacing the atrium. In eight experiments, a special multipolar, tubular electrode was introduced through the free wall of the right ventricle near the anterior AV junction. It was held in place by a purse-string suture into the free wall of the right ventricle so that the electrode would be in stable contact with the proximal right bundle branch (Fig 2). Initially, we determined the threshold for pacing at the RV apex. The first channel of a Grass S-88, two-channel stimulator that delivered stimuli to drive the atrial pacing impulse was also set to trigger pulse trains from the second channel to the RV electrodes at 1000 Hz, with a delay of 80 to 100 milliseconds from the atrial pacing impulse. Each pulse of the train was 0.5 millisecond in duration, and the duration of the pulse train was 50 milliseconds. The large tip was used as the cathode, and the other seven electrodes were connected to form a large anode (Fig 2). In most cases, constant DC was also delivered to the RV apex either during sinus rhythm or during atrial pacing at various pacing rates.

Application of Subthreshold Stimulation to the His Bundle Area

Another group of 12 mongrel dogs was anesthetized as described above. The same procedures for delivery of drugs, blood pressure recording, ECG, and His bundle recordings were used as described previously. The right heart was exposed by thoracotomy at the fourth intercostal space, and plunge-wire electrodes were placed into the RV epicardium at the RV apex and outflow tracts for introduction of premature ventricular stimuli. A deflectable-tip electrode catheter (four or six rings, 4 mm apart) was introduced through the right jugular vein into the right ventricle. In six dogs, the tip was placed under the septal leaflet of the tricuspid valve to record His bundle activity at the crest of the interventricular septum. SS in the form of pulse trains (as described above) was delivered to the electrodes under the tricuspid valve with the tip electrode serving as cathode and the other three or five electrodes serving as a combined anode. Each train was coupled to a high right atrial pacing stimulus with a delay of 60 to 80 milliseconds. Another form of SS was delivered to this same electrode arrangement as a constant DC pulse of variable duration (30 seconds to 2 minutes). During SS, premature ventricular beats (PVB) were elicited by suprathreshold stimuli delivered to the RV apex or outflow tract. These PVBs were delivered after every eighth atrial paced beat, with variable coupling intervals ranging from the ventricular functional refractory point to that producing fusion with the next paced beat.

To verify that SS was truly subthreshold, two tests were applied: (1) During SS that induced ECG changes indicative of preexcitation, AV conduction was abruptly blocked by strong vagosympathetic truck stimulation. (2) When subthreshold pulse trains coupled to an atrial pacing stimulus induced preexcitation, atrial pacing was discontinued, thereby allowing the pulse trains to traverse the cardiac cycle, including the diastolic interval.

All recordings were monitored on an Electronics for Medicine oscillographic/photographic recorder that was interfaced to a Gould ES1000 monitor/recorder to obtain hard copy of the data on electrostatic paper at speeds ranging from 25 to 250 mm/s. ECGs were recorded with standard filters at 0.03 to 250 Hz; electrogams were recorded with filter settings of 30 to 250 Hz.

Animal studies were performed in accordance with guidelines established by the National Institutes of Health and state regulations from the US Department of Agriculture. In addition, all protocols were approved by the Animal Studies Subcommittee and the Research and Development Commit-
block and slow idioventricular rhythm persisted unchanged during the same DC current application.

Ectopic conduction is a special form of anomalous conduction that occurs at the damaged interface between specialized and regular myocardium. The cardiac impulse prematurely exits from the AV specialized conduction system to activate adjacent regular muscle. During retrograde conduction from a ventricular muscle site of excitation, the impulse can enter the proximal specialized conduction tissue without first traversing Purkinje-muscle junctions.

The Wedensky effect relates to a concept originally developed in nerve in which a strong shock delivered proximal to an area of block alters the excitability distal to the site of block so that it becomes more susceptible to activation, that is, lowered threshold of excitability. Thus, local responses emanating from either a strong or subthreshold impulse may excite distal to the block site after penetration of the blocked zone. Similarly, such local responses acting on the distal site may inhibit or suppress conduction. These phenomena have been described as Wedensky facilitation or inhibition, respectively. More recently, the cellular electrophysiological mechanism by which subthreshold stimuli act in this setting has been elucidated by Antzelevitch and Moe in a model of local block using a free-running Purkinje fiber preparation.

Results
Subthreshold Stimulation to the RV Apex

A typical recording made during the present studies is shown in Fig 4, in which the atrium was paced at 200 beats per minute (Fig 4A) and ECG leads II, aVR, and a standard His bundle electrogram were recorded. Vagosympathetic trunk stimulation abruptly produced complete AV nodal block. A subthreshold train of square wave pulses triggered by each atrial pacing stimulus was then delivered to the RV apex (Fig 4B). The duration of each square wave was 0.5 milliseconds, the frequency of the pulses was 1000 Hz, and the duration of the train was 50 milliseconds. Each pulse train (0.1 mA) was delayed 80 to 100 milliseconds from the atrial pacing impulse to fall during the HV interval. Note that this SS was associated with a shortened PR interval because of a decrease in the HV interval from 40 milliseconds (control) to 25 milliseconds and was associated with a LBBB pattern in the ECG leads. In this case, a small delta wave preceded the aberrant ventricular depolarization. The onset of vagosympathetic trunk stimulation resulted in one beat, with a prolonged AH interval of 110 milliseconds and a negative HV interval of 15 milliseconds. Note that all the other AH intervals in the control state and during the Prinzmetal effect were the same: 90 milliseconds. These findings will be discussed in detail below.

The threshold (in milliamperes) to induce constant ventricular pacing from the RV apex was determined using a 2-millisecond pulse (Table 1, first column). The level of stimulation in milliamperes required to produce the Prinzmetal effect was determined using pulse trains or constant DC current (Table 1, second column). There was a significant difference between threshold and subthreshold levels of stimulation ($P=.007$). One of the consistent responses to SS, which caused PR shortening at any given heart rate, was the concurrent shortening of the HV interval. Table 2 shows the results of a paired $t$ test applied to the changes in the HV interval before and after the application of SS to the RV apex. The mean HV interval during the control state
was 35±4 milliseconds (mean±SD) versus 19±7 milliseconds in response to SS (P=.0001).

Not all results of SS at the RV apex were associated with typical delta waves in leads II and aVR. In Fig 5, an alternating form of preexcitation similar to that described by Prinzmetal et al was seen during delivery of constant DC current of 0.2 mA to the catheter in the RV apex. In addition to the ECG and His bundle recordings, we used a special tubular electrode (Fig 2) that could be inserted, rotated, and fixed against the basal RV septum so that one or more bipolar pairs would record potentials from the proximal right bundle branch. Application of DC constant current induced a shortened PR interval and aberrant ventricular depolarization that was preceded by an abbreviated positive delta wave followed by a large, wide Q wave in lead II. This response occurred in only 2 of 10 cases. The QRS duration was 85 milliseconds compared with the normal duration, 50 milliseconds, and its morphology allowed a classification of LBBB. The intracardiac recordings clearly show the maintenance of the normal sequence of

His bundle and right bundle activation. However, a prominent "slow" deflection arising in the vicinity of the proximal right bundle was observed in this and other experiments. In this case, the HV interval decrease from 30 to 5 milliseconds was atypical (Table 2). In all cases, the appearance of a slow potential in the vicinity of the proximal right bundle branch distorted the normal isoelectric RbV interval. These potentials were consistently coincident with the onset of delta waves on the surface ECG associated with the shortened PR intervals. The significance of these slow waves will be discussed below.

In all cases, the subthreshold nature of the stimulus was attested to by the response to vagally induced complete AV nodal block (Fig 6). The first beat shows normal PQRS (ECG leads I to III) and HV interval (30 milliseconds) during atrial pacing at 150 per minute. In response to a coupled pulse train (0.34 mA) delivered during the latter half of the PR segment, the HV shortened by 10 milliseconds and the QRS showed a

### Table 1. Suprathreshold Pacing and Prinzmetal Effect With Subthreshold Stimuli

<table>
<thead>
<tr>
<th>Dog</th>
<th>Regular Pacing, mA</th>
<th>Prinzmetal Effect, mA</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>3.3</td>
<td>2.0</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>0.7</td>
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<tr>
<td>3</td>
<td>1.2</td>
<td>0.7</td>
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<tr>
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<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>5</td>
<td>1.3</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>1.3</td>
<td>0.2</td>
</tr>
<tr>
<td>7</td>
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<td>0.2</td>
</tr>
<tr>
<td>8</td>
<td>0.4</td>
<td>0.3</td>
</tr>
<tr>
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<td>0.1</td>
</tr>
<tr>
<td>10</td>
<td>2.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Mean±SD 1.3±0.9 0.6±0.6

P=.007

### Table 2. Alteration in HV Interval During Prinzmetal Effect

<table>
<thead>
<tr>
<th>Dog</th>
<th>Control, ms</th>
<th>Prinzmetal Effect, ms</th>
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<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>25</td>
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<td>2</td>
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<td>10</td>
<td>35</td>
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</table>

Mean±SD 35±4 19±7

P=.0001
LBBB pattern with a deep and widened Q wave, as seen in Fig 5. With the onset of vagally induced AV nodal block, no ventricular excitation was observed until normal conduction resumed intermittently three atrial paced beats later. This response to complete AV block during the Prinzmetal effect was not seen often. More commonly, there was a transient continuation of AV conduction with aberrant ventricular depolarizations (for one or more beats). However, complete or high-grade block always superseded, as seen in Fig 6.

Subthreshold Stimulation to the His Bundle Area

Manifest forms of preexcitation were seen in 4 of 12 dogs as a result of SS applied to the His bundle area. Although the effects of SS were generally similar to SS delivered at the RV apex, there were some specific differences. Fig 7 shows the effects of a constant DC current (0.25 mA) delivered to the catheter electrodes under the septal tricuspid leaflet. As with SS to the RV apex, preexcitation is evident by delta waves (Fig 7B), HV shortening (30 to 10 milliseconds), and an unchanged AH interval (45 milliseconds). However, the ventricular depolarization showed much less change in the degree of aberration and prolongation of duration with SS applied to the His bundle area than that observed during SS applied to the RV apex.

An examination of the His bundle electrogram provides some basis for these differences. The last deflection of the ventricular potential in the control state (Fig 7A) occurs after the end of the surface ventricular complex. With the local application of constant DC current (0.25 mA), the previously late septal crest potential now preceded the onset of ventricular depolarization (Fig 7B) and coincides temporally with the
delta waves. This response to SS, that is, alterations both in the ECG and His bundle electrogram, were seen in 4 of 12 dogs.

In 6 of 12 cases, latent forms of preexcitation induced by SS were seen that consisted of a shortened HV interval without noticeable change in the recorded surface ECG leads. In Fig 8A, 0.65-mA pulse trains coupled to each atrial pacing stimulus were delivered to the electrodes under the septal leaflet of the tricuspid valve. No changes either in the ECG leads or the HV interval were noted (HV, 30 milliseconds, as in the nonstimulated state). In Fig 8B, when the subthreshold stimulus intensity was raised to 0.80 mA, the septal crest potential shifted from the end toward the beginning of ventricular depolarization with a shortened HV interval of 20 milliseconds. However, no changes in the QRS complexes were seen during latent preexcitation. Two of the six dogs showed both latent and manifest forms, depending on the level of the subthreshold stimuli applied.

That the stimuli inducing these effects are truly subthreshold was evident in another experiment when atrial pacing was terminated during manifest preexcitation. In Fig 9, the pulse train (current level, 0.5 mA), when uncoupled from the atrial pacing stimulus, tracked through the cardiac cycle. Only when the subthreshold pulse train fell within the PR segment was there an alteration of either the His bundle electrogram, that is, advance of the septal crest potential (Fig 9A, first to third beat), or both the His bundle electrogram and ECG (Fig 9A, fourth and fifth beat). When the pulse train fell during the diastolic period, the TP interval (Fig 9B), no electrophysiological changes were seen, thus verifying the subthreshold level of these pulse trains.

Under conditions of constant SS that induced only latent preexcitation, the delivery of a strong (28-mA) stimulus to the ventricle converted the latent to a manifest form of preexcitation. In Fig 10, the first two beats exhibit latent preexcitation induced by the sub-
threshold pulse trains (0.4 mA) coupled to each atrial pacing stimulus. Note the early activation of the septal crest potential. The delivery of a strong (28-mA) ventricular extrastimulus caused a PVB followed by manifest preexcitation of the next atrial paced beat. Both the ECG and His bundle electrogram recordings were appropriately altered.

In some cases, an interposed PVB inhibited either the latent or the manifest form of preexcitation, converting the following beat to normal. Fig 11A shows that 0.45-mA pulse trains delivered during the PR segment induced a shift of the septal crest potential toward the middle of the unchanged QRS complex in lead II. In Fig 11A, a PVB delivered to the RV outflow tract (coupling interval, 360 milliseconds) was associated with the loss of latent preexcitation in the subsequent atrial paced beat. Note the normal late septal crest potential and the normal HV interval (30 milliseconds). In Fig 11B, a higher-intensity pulse train (0.6 mA) induced manifest preexcitation and no diminution of the initial Q and R waves in leads II and aVR, respectively; also, there was the occurrence of taller and wider ventricular depolarizations, from 60 milliseconds for the normal QRS to 90 milliseconds and LBBB pattern in the first two beats shown in Fig 11B. A PVB delivered from the posterior RV apex with a coupling interval of 380 milliseconds again is followed by a normal atrial paced beat, that is, inhibition of preexcitation.

Discussion
Effects of Subthreshold Stimulation in the Normal Dog Heart

In his monograph, Prinzmetal and his associates described chemical, mechanical, and electrical stimulation of the RV endocardial surface that induced a consistent shortening of the PR interval associated with WPW-like changes in the QRS complex. Before our awareness of these investigations, reports from our laboratory detailed similar changes, particularly regarding delta wave induction in dog hearts, in which the interface between the His bundle and ventricular septum had been damaged by chemical means, ie, by lidocaine or ischemia. We coined the expression "ectopic conduction" to describe the premature exit of the impulse from the normal conduction pathways to adjacent myocardium. However, in these cases, there was an associated prolongation of the PR interval mainly caused by a marked intra-His bundle block.

As originally described by Prinzmetal et al, the application of subthreshold DC current to the RV endocardium was the most effective means of producing what appeared to be the ECG manifestations of the WPW syndrome. It should be noted that in these experiments, as in the present studies, no arrhythmias were induced. However, in the present studies, additional electrical recordings were made from the His and right bundle branches. Our findings for the most part confirm and extend the results and some of the conclusions of Prinzmetal et al. Delivery of SS in the form of DC constant current or pulse trains synchronized to an atrial pacing spike consistently shortened the PR interval, as found by Prinzmetal et al. The His bundle recordings alone allowed us to determine that AV nodal conduction, that is, the AH interval, was consistently unaffected, whereas the HV interval was significantly shortened (Table 2). Thus, these data do not support the original postulation by Prinzmetal et al that accelerated AV nodal conduction is the explanation of the effect but do indicate that the site of preexcitation was localized in proximal portions of the His-Purkinje system. Even when SS was applied at the RV apex, localization of preexcitation was found in recordings from the area of the proximal right bundle branch and its adjacent septal muscle. The Prinzmetal effect was consistently associated with the appearance of a relatively slow depolarization in the vicinity of the proximal right bundle branch even though the site of subthreshold application was 3 to 4 cm distant to that site. Thus, the sequence of His bundle—right bundle activation was maintained in the abnormal beats, and the slow wave, recorded endocardially, was always coincident with the delta wave seen in the surface ECGs. It is important to point out that when subthreshold stimuli were applied to the RV apex, the delta waves were not uniform. The different varieties are shown in Figs 4 and 5. Either there was a typical initial slurred onset of the ventricular depolarization (Fig 4B) or an attenuated slurred R wave followed by an S and R' (Fig 5). In the first instance, the ventricular depolarization took the form of functional LBBB, that is, early activation of the right septal surface and late activation of the left septal surface. This would result in the diminution of the initial left to right septal vector (Q wave). The RSR'
configuration may represent a fusion complex between initial but incomplete septal activation close to the proximal bundle and normal activation of the rest of the ventricles.

That either form of ventricular aberration was not due to direct stimulation of the right ventricle at the apex (where the subthreshold stimuli were delivered) is evidenced by (1) the normal sequence of His and right bundle activation during the Prinzmetal effect. If the ventricular beat had been directly excited at the RV apex, then the activation sequence would have been reversed as seen in the fourth beat (Fig 5), which is a ventricular ectopic beat probably arising from the apex. (2) Vagally induced complete AV nodal block revealed that the stimulus delivered to the apex was only transiently but not consistently excitatory (Fig 4B). Whatever its mode of occurrence, either abrupt or progressive, vagally induced complete AV block was always associated with loss of preexcitation.

There was at least one ventricular excitation that occurred immediately after the onset of vagally induced AV block (Fig 4B). Characteristically, this beat showed a prolonged AH interval and a greater degree of LBBB than the beats before the onset of vagal stimulation. Thus, unlike the Prinzmetal effect, which presumably induced premature exit of the propagating sinus impulse at the proximal right bundle to adjacent myocardium, this excited beat probably arose in the vicinity of the tip of the electrode catheter at the RV apex, that is, at the site of delivery of SS. Such a transient excitatory effect of SS has been described under various circumstances in nerve and heart as the Wedensky effect. Briefly stated, it is the concept that some ectopic beats can be due to a local change in excitability, in this case caused by the subthreshold stimulus. The source of the subthreshold stimulus can serve as a site of “cathodal block,” with a resulting increase in excitability just distal to that blocked site. Excitability at such a site immediately after a conditioning threshold or subthreshold stimulus is markedly decreased and with time increases to threshold and even above threshold levels. Importantly, this altered excitability is dependent on a dominant or triggering impulse. Also, it has been noted that these beats are transient, which is in keeping with the gradual increase in excitability described above.

As might be expected, these findings on the effects of SS in the normal heart raised many questions: What is the mechanism by which the impulse can prematurely exit from supposedly insulated portions of the AV conducting system in response to a supraventricular beat and background SS? In our previous studies, damage to the interface between the His bundle and underlying septal crest muscle or the right bundle and adjacent myocardium induced ectopic conduction without the need for subthreshold stimuli. This effect occurred in about 40% of the experiments. In the present studies, it is difficult to accept that subthreshold stimuli could have induced damage of adjacent Purkinje and muscle membranes so that ectopic conduction could occur within the period of a few beats. Perhaps the presumed electrical insulation between Purkinje and muscle cells, particularly at the proximal portions of the His-Purkinje system, is relative as a high-resistance connection that can be altered by the interaction of a supraventricular beat and SS applied locally or even at a distance. Baird and Robb showed in the dog heart that the His bundle and the proximal portions of the right bundle are not separated by a connective tissue sheath, as is the case in the more distal parts of the bundle and its arborizations. Lev also showed similar findings in humans. Thus, the cardiac impulse that consists of a passive or electrotonic component and an active component can have the former summated with the artificially induced subthreshold stimulus. This summated electrotonic influence could cross the interstitial space, that is, Purkinje and muscle cells that are separated by a relatively inexitable gap. If this activation (represented by the slow, relatively low-level deflection seen in Figs 5 and 6) caused the membrane potential of the muscle to reach threshold, it can be depolarized before its normal activation from the more peripheral Purkinje-muscle junctions.

Recent studies by Antzelevitch and Moe have shown that subthreshold stimuli can be summed with local electrotonic currents to successfully bridge an inexitable gap artificially created in the middle of an isolated Purkinje fiber. Excitation of the distal side of the gap was thereby achieved. Our preliminary studies in vitro have clearly reproduced the Prinzmetal effect in the isolated tissue preparation. However, in these preparations from normal heart, we have not been able to localize the cellular features associated with the supposed electrotonic crossover from proximal bundle to adjacent muscle. In our previous studies of damage-induced ectopic conduction, we found foot potentials at the site of “slow conduction” between Purkinje cells of the right bundle branch and adjacent myocardium. More in vitro studies are required to clarify the cellular correlates of the Prinzmetal effect.

**Interaction of Wedensky Phenomenon and the Prinzmetal Effect**

The previous discussion has already implicated the role of the Wedensky phenomenon, that is, transient enhanced excitability distal to a site of the block caused by SS. In the experiments in which the subthreshold stimuli were delivered under the tricuspid septal leaflet, premature ventricular stimuli provided further evidence of interaction between the Prinzmetal and Wedensky effects. In our studies, titration of subthreshold stimuli to the ventricular septal crest induced a local Prinzmetal effect, that is, shift of septal activation from the end toward the beginning of ventricular depolarization (Figs 8 and 9). However, the amount of tissue activated was apparently too small to alter the body surface recordings (Fig 8); thus, preexcitation was latent in the ECG. We postulate that the introduction of a PVB even at a distance from the interventricular septal crest serves as another conditioning component whose electrotonic contribution further enhances excitability in the critical area, thereby potentiating excitation of the region. A greater area now activated, a more intense excitation, or both lead to manifest preexcitation in the surface ECG leads.

A similar observation has been made in patients showing antegrade block of accessory pathway conduction at particular heart rates. A PVB could restore antegrade accessory pathway conduction, albeit in a series of paced beats subsequent to the ectopic beat.
Possible mechanisms for this response were "peeling" back of a refractory barrier, supraventricular conduction, or Wedensky facilitation.35

The apparent induction of inhibition of latent preexcitation by premature beats delivered at the RV apex or outflow tract is more difficult to explain. Although it would seem to be an example of Wedensky inhibition, the possibility of catheter movement caused by postextrastolic-enhanced contraction cannot be ignored. Further studies in vivo, particularly with multielectrode mapping techniques, and in vitro should be carried out to fully explore the basis for Wedensky facilitation and inhibition in the context of the Prinzmetal effect.

Clinical Implications

Inhibition of left-sided accessory pathway conduction has been described by Gang et al36 using SS applied to the coronary sinus area. Reciprocating tachycardias were terminated using this method in 7 of 10 patients. More recently, Fromer and Shenasa37 used subthreshold stimuli applied to the proximal coronary sinus or low atrial septum to terminate AV nodal reentrant tachycardia in 15 patients. These authors found that facilitated conduction, manifested in shortening of the tachycardia cycle length before termination, may have played a role in termination. They specifically cite the Prinzmetal effect as a possible mechanism for these findings. In this regard, SS could be used as a reproducible means to determine which of various sites at the AV junction are optimal for radiofrequency ablation.38

Another possible use for SS would be its application at ventricular insertion sites of concealed accessory bypass tracts, for example, those showing only retrograde conduction. Would SS at this site result in successful antegrade propagation over the accessory pathway, thus pinpointing the target for ablation? SS delivered to the accessory pathway insertion in patients with intermittent preexcitation, directly converting normal conduction to consistent preexcitation,38 demonstrates the feasibility of this approach. The ability of PVB to convert normal conduction to preexcitation in patients with latent preexcitation has already been cited.35 With further basic studies and greater understanding of the mechanisms of the Prinzmetal effect, new clinical uses may be found for this unusual response to SS.

Acknowledgments

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