A Study on Sinoatrial Conduction in the Aged

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SUMMARY

Sinus node response to premature atrial stimulation (PAS) was studied in 30 aged patients (group I: 21 cases without sinus node dysfunction, group II: 9 cases with sick sinus syndrome). Sinoatrial conduction time (SACT) was calculated according to the method reported by Strauss et al.

As coupling interval of PAS decreased, there noted 5 patterns of sinus node response. In Type A, return cycle length (RC) initially increased (fully compensatory pause) and then became constant; RC progressively increased either along the compensatory reference line (Type B₁) or along the less-than-compensatory line (Type B₂) without being constant. In 2 other cases, RC showed similar pattern as in Type A up to 32-37% of sinus cycle length where they showed abrupt prolongation below or above the compensatory reference line (Types C and D, respectively).

The incidence of abnormal response (Types B₁, B₂, C, and D) was high both in group I (38.0%) and group II (33.3%). The calculated SACT in group I showed a high correlation with basic sinus cycle length, while no correlation was observed in group II.

The possible factors influencing return cycle length and significance of frequent observation of abnormal sinus nodal responses in the aged subjects were discussed.

Additional Indexing Words:

Sick sinus syndrome Sinoatrial conduction time Sinus node automaticity Sinoatrial block

WITH the recognition of the prevalence of the syndrome of sinus node dysfunction (sick sinus syndrome),¹⁻³⁾ a growing interest has been focused on the clinical methods by which sinus node function can be evaluated in normal and abnormal subjects.

Recently, technics of rapid atrial pacing^{4),5)} and premature atrial stimulation (PAS)⁶⁾ have been introduced to evaluate sinus node dysfunction. Using

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the technique of PAS, we evaluated sinoatrial conduction in 30 aged patients, in whom sinus node dysfunction was relatively common.

PATIENTS AND METHODS

Consecutive 30 cases, aged 62 to 90 years, were selected from those scheduled for electrophysiological study, excluding cases with sinus arrhythmias with variation of cycle length exceeding 0.16 sec at the time of the study.

Group I; Twenty-one cases (cases 1~21, 10 males and 11 females) had various types of conduction disturbances, such as atrioventricular block, bundle branch block, or WPW syndrome as listed in Table I, but had no clinical signs of sinus node dysfunction. Their age ranged from 62 to 88 years.

Group II; Nine cases (cases 22~30, 5 males and 4 females) had clinical presentations to be felt to represent sinus node dysfunction. Six cases had episodes of alternating sinus bradycardia and supraventricular tachycardia (so-called bradycardia-tachycardia syndrome), 2 had episodes of spontaneous sinoatrial block, 1

Table I. Group I

No.	Name	Age & Sex	Electrocardiographic Diagnosis	BSCL (msec)	Type	SACT (msec)
1	I. T.	62 F	3° A-V block	840	A	93
2	S. K.	81 M	Advanced A-V block	1,340	A	121
3	H. T.	78 F	2° A-V block	771	A	77
4	S. M.	78 F	WPW syndrome	608	A	58
5	K. M.	70 F	RBBB	1,112	A	106
6	Y. A.	70 F	RBBB	934	A	145
7	S. S.	88 M	3° A-V block	880	A	95
8	S. N.	65 M	3° A-V block	800	A	100
9	M. W.	69 M	normal	1,140	A	105
10	T. N.	71 M	normal	720	A	109
11	N. M.	79 M	3° A-V block	1,130	A	100
12	N. T.	77 F	CRBBB, LAD	680	A	70
13	I. O.	79 M	1° A-V block	1,100	A	90
14	K. H.	74 F	WPW syndrome		B ₂	
15	S. O.	81 M	1° A-V block		B ₂	
16	T. O.	82 F	1° A-V block, RBBB		B ₂	
17	S. N.	78 F	3° A-V block		B ₂	
18	T. H.	73 M	incomplete RBBB		B ₂	
19	K. H.	66 M	2° A-V block		B ₂	
20	K. H.	71 F	WPW syndrome	1,100	C	(111)
21	Y. U.	69 M	1° A-V block	1,000	D	(85)

BSCL: basic sinus cycle length, SACT: sinoatrial conduction time,
RBBB: right bundle branch block, A-V block; atrioventricular block,
M: male, F: female

Table II. Group II (Sick Sinus Syndrome)

No.	Name	Age & Sex	Electrocardiographic Diagnosis	BSCL (msec)	Type	SACT (msec)
22	T. T.	73 M	Brady-tachy syndrome	1,450	A	132
23	M. I.	65 M	Sinus bradycardia	1,653	A	145
24	T. I.	66 M	Brady-tachy syndrome	1,000	A	82
25	T. G.	74 M	S-A block	1,200	A	200
26	Y. O.	76 F	Brady-tachy syndrome	1,000	A	155
27	T. U.	80 F	S-A block	674	A	110
28	S. A.	77 M	Brady-tachy syndrome	974	B ₁	
29	T. Y.	90 F	Brady-tachy syndrome	1,132	B ₂	
30	R. N.	86 F	Brady-tachy syndrome	964	B ₂	

Brady-tachy syndrome : bradycardia-tachycardia syndrome

with sinus bradycardia with rate less than 40/min (Table II). Their age ranged from 66 to 90 years.

Methods:

All patients were studied in postabsorptive state and did not receive any cardioactive drugs unless otherwise stated.

A bipolar electrode catheter was inserted via the basilic vein and the tip was placed at the lateral wall of high right atrium. The catheter was used for recording of the intraatrial electrogram to initiate programmable stimulator and for delivering rapid stimuli or a single premature stimulation (PAS) after every fifth spontaneous sinus cycle. Rectangular stimuli of 2 msec in duration and twice diastolic threshold were delivered through the catheter via an isolated transformer (Nihon Koden type MDP-2-DS) with pre-set time delay after the last spontaneous atrial depolarization.

A bipolar or quadripolar electrode catheter was inserted via the femoral vein and was used for recording of electrogram in lower right atrium (RAE) and of His bundle electrogram (HBE).

All the above signals and 3 leads of electrocardiograms (lead I, aVf, and V1) were simultaneously displayed on an Electronics for Medicine multichannel oscillograph and recorded on photographic paper at a speed of 50 or 100 mm/sec, and also on FM magnetic tape.

Measurements and calculations:

Following time intervals were measured; 1) basic cycle length: the interval between the last 2 sinus P waves before applying PAS, 2) test cycle length: the coupling interval of PAS-induced atrial depolarization, 3) return cycle length: the interval between PAS-induced atrial depolarization and the next spontaneous sinus P wave. The lengths of test cycle and return cycle were normalized by dividing by the basic cycle length.

Normalized return cycle length was plotted as a function of normalized test cycle length in individual case. When PASs were delivered in late atrial diastole, the test cycles were followed by fully compensatory pauses (compensatory zone). When the return cycle length remained constant following earlier PASs (reset zone),

mean sinoatrial conduction time (SACT) was calculated using previously published principles.⁶⁾ In cases in whom the return cycle length did not show constant level of reset zone, no SACT was obtainable.

The intervals between the PASs and depolarization waves of the lower right atrium on HBE at the shortest test cycle which was accompanied by atrial depolarization were measured and designated as intraatrial conduction time in this study.

RESULTS

I. Types of sinus node response to PAS

In 13 cases of group I (cases 1–13), PAS elicited in late diastole was followed by return cycles that were fully compensatory (compensatory zone), and progressive shortening of test cycle length resulted in constant duration of return cycle (reset zone), which was slightly greater than one spontaneous sinus cycle length. We have designated this type of response as Type A (Fig. 1-A).

In 6 cases of group I (cases 14–19), the plot of normalized return cycle versus normalized test cycle did not show a plateau after the transition from fully compensatory pause, but return cycle was progressively prolonged with increasing prematurity of PASs. The plot then followed a diagonal line which was below and to the left of the compensatory reference line, and this type of response was designated as Type B₂ (Fig. 1-C).

In 2 other cases of group I (cases 20 and 21), return cycle length remained constant with earlier PASs as those in Type A, until the test cycle reached 32% (case 20) or 37% (case 21) of the sinus cycle length where they were

Fig. 1. Types of sinus node response to PAS. (A) Type A response, (B) Type B₁ response, (C) Type B₂ response.

Fig. 2. Type C response of the sinus node to PAS.

Fig. 3. Type D response of the sinus node to PAS.

abruptly prolonged. In case 20, the sum of abruptly-prolonged return cycle length and test cycle length was slightly less than twice the basic sinus cycle length (Type C, Fig. 2). In case 21, the sum mentioned above exceeded twice the basic sinus cycle length (Type D, Fig. 3). In cases 20 and 21, intraatrial conduction time was 60 and 50 msec, respectively, which were not long, when compared to those for the rest of the cases.

In group II (sick sinus syndrome), 6 cases (cases 22–27) showed Type A response. In 1 case (case 28), the plot of normalized return cycle versus

Fig. 4. Relation between sinoatrial conduction time and basic sinus cycle length in cases of Group I (left) and those of Group II (right).

normalized test cycle followed the line of fully compensatory pauses during whole range of test cycles, and this type of response was designated as Type B₁ (Fig. 1-B). Type B₂ response above mentioned was observed in 2 cases of group II (cases 29 and 30).

II. Calculated sinoatrial conduction time (SACT)

In cases presenting Type A response, SACT ranged from 70 to 145 msec in group I and 82 to 200 msec in group II. In cases 20 (Type C) and 21 (Type D), plateau levels of return cycle length with PASs in the middle of diastole were used for calculation of SACT, which were 111 msec and 85 msec, respectively.

The calculated SACT in group I showed a high correlation with basic sinus cycle length ($r=0.563$, $p<0.05$) (Fig. 4-A), while no correlation was observed in group II. In 12 cases of group I in whom sinus cycle length was shorter than 1,200 msec (heart rate, more than 50/min), SACT was shorter than 1,200 msec (heart rate, more than 50/min), SACT was shorter than 110 msec except in 1 case (case 6). In 1 other case (case 2), prolonged SACT (121 msec) was nearly proportional to a long basic sinus cycle (1,340 msec). The average SACT in group I was 97.5 ± 21.3 (SD) msec, while the average basic sinus cycle length was 927.3 ± 210.7 (SD) msec.

DISCUSSION

The principles by which SACT was measured in man by Strauss et al⁽⁶⁾ involve the delivery of PAS through an electrode in high right atrium and analysis of sinus node response to PAS. The studies with this method in

rabbit,⁷⁾⁻⁹⁾ dog,¹⁰⁾ and men¹¹⁾⁻¹³⁾ have been reported. The comparison of these results showed similarities and differences, and basic electrophysiological properties of the sinus node and perinodal fibers have been evaluated in animal studies.

In rabbit hearts, Miller and Strauss⁹⁾ reported shortening of return cycle length with earlier PASs and this phenomenon was ascribed to shortening of sinus node action potential due to electrotonic interaction. Depression of the sinus node automaticity⁷⁾ and shift of dominant pacemaker to those with slower rate have been also observed in rabbit.⁷⁾ Thus comparing the curves obtained in rabbit and human studies, Miller et al⁹⁾ noted infrequent occurrence of plateau response in rabbit heart. In intact dog hearts Ticzon et al¹⁰⁾ could identify 4 zones (compensatory zone, reset zone, interpolation zone, and echo zone) from the plots of return cycles versus test cycles.

In human studies, reported by Strauss et al,⁶⁾ Engel et al,¹¹⁾ and by Sheinman et al,¹²⁾ the transition from a compensatory return cycle to a constant but less than compensatory return cycle, which was common observation in their cases, has been interpreted as signifying the transition from non-capture of the sinus node by PAS. This plateau response was not observed in cases reported by Steinbeck et al.^{15),16)}

The present study on aged patients showed the plateau response with a sharp transition from compensatory zone to reset zone were observed in 21 cases (Type A 19 cases, Type C 1, and Type D 1), of which 15 belonged to Group I and 6 to Group II. The incidence of this occurrence in Groups I and II was 60% and 66.6%, respectively. Comparable study on the incidence of normal and abnormal responses to PASs among aged patients, to our knowledge, has not been reported.

In the rest of the cases (6 of Group I and 3 of Group II), return cycle length was prolonged progressively as the prematurity of the test cycle length was increased. In 1 of them, the plots of return cycle length versus test cycle length with earlier PAS still followed the line of fully compensatory sinoatrial response (Type B₁), which was interpreted as representing first degree sinoatrial block.⁶⁾ In other 8 cases, however, the plots followed a diagonal line which was less and to the left of the reference compensatory line (Type B₂), which resembled the cases reported by Steinbeck et al.^{15),16)} They calculated SACT from the return cycle length at the turning point from full compensatory to non-compensatory pause with the assumption that at this point retrograde activation time of sinus node by PAS was shortest. The direct evidence to substantiate this assumption, however, has not been available thus far.

Various factors which influence the return cycle length in noncompensatory

satory zone have been proposed in animal and human studies. Those factors resulting in shortening of return cycle include electrotonic effect of PAS which accompanies shortening of sinus node action potential duration,⁹⁾ sinus node reentry,^{8),18)} supernormal phase of retrograde atrio-sinus conduction.¹⁹⁾ Return cycle length which was identical to the spontaneous sinus cycle length during the whole range of prematurity, possibly due to direct stimulation of the sinus node, were also reported in man.²⁰⁾

On the other hand, factors resulting in unexpected prolongation of the return cycle length include delayed retrograde conduction from the atrium to the sinus node,⁶⁾ shift to the pacemaker with slower rate,⁷⁾ and depressant effect of PAS to sinus node automaticity.^{15),21)}

Although species difference may be present, superimposition or counterbalancing of these factors may occur, then it may be difficult to delineate underlying mechanism controlling the changes of the plots in human studies. Although several possibilities may be conceivable to explain Type B₂ response in this study (Fig. 5), direct evidence to support any of these was not obtained in the present study. Therefore, the curves following either a compensatory or a less-than-compensatory line with earlier PASs preclude an accurate estimation of SACT, thus limiting the application of this method. But, it should be noted that Type B₂ response was frequently observed in aged patients, notwithstanding the presence or absence of clinical presentation of sinus node dysfunction. This fact may imply that electrophysiological properties of the sinus node or in peri-nodal fiber are frequently impaired in aged patients with other types of conduction disturbances.

The responses observed in cases 20 (Type C) and 21 (Type D), in whom sudden, unexpected prolongation of return cycle length with very early PASs, have not been reported in the electrophysiologic study in man with this technique. This "jump up" may represent depressant effect of early PAS on pacemaker automaticity and/or prolonged retrograde atrio-sinus conduction during relative refractory period of the peri-nodal fiber, but not due to delay in intraatrial conduction, because intraatrial conduction was not prolonged.

In the present study, calculated SACT in group I was 97.5 ± 21.3 msec ($m \pm SD$), which is close to normal value of SACT 82 ± 18.7 msec reported by Seipel et al.¹⁷⁾ Total sinoatrial conduction time, which is equal to twice the calculated SACT by Strauss's principle, in normal subjects was reported to be 220 ± 40 msec by Scheinman et al.¹²⁾ and 169 ± 91.6 msec by Engel et al.¹¹⁾ These authors¹¹⁾ also reported that prolongation of SACT was frequently observed in patients with sick sinus syndrome.

It should be noted that calculated SACT in group I showed a high correlation with basic sinus cycle length, indicating the importance of evaluating

Fig. 5. Possible explanations of Type B₂ atrial response to premature atrial depolarization. $P_1 - P_1$ = basic cycle length, P_2 = premature atrial depolarization, P_3 = atrial return cycle response, $P_1 - P_2$ = test cycle, $P_2 - P_3$ = atrial return cycle, SAN = sinoatrial node. Compensatory line is the plot of $(P_1 - P_2)/(P_1 - P_1)$ versus $(P_2 - P_3)/(P_1 - P_1)$ when $(P_1 - P_2) + (P_2 - P_3) = 2(P_1 - P_1)$. (A): Compensatory return cycles occur with P_2 ① and P_2 ②. Sinus node capture occur with earlier premature atrial depolarizations (P_2 ③ and P_2 ④), but less than compensatory return cycle occur because of depressed sinus node automaticity with these earlier atrial depolarizations. (B): In the presence of prolongation of both sinoatrial and atriosinus conduction, premature atrial depolarizations (P_2 ① - P_2 ④) do not capture the SAN, but less than compensatory return cycles occur because of the shortening of sinus cycle length due to electrotonic effect of premature atrial depolarizations. (C): Compensatory return cycle occur with P_2 ①. Less than compensatory return cycle occur with P_2 ② when sinus node capture do not occur, but sinus cycle length is shortened due to electrotonic effect of P_2 ③. Sinus node capture occur with P_2 ③ and P_2 ④, but less than compensatory return cycle occur due to depressive effects on the SAN.

the value of calculated SACT in its relation to basic sinus cycle length in aged subjects. In 5 out of 6 cases of group II, calculated SACT was equal to or exceeded 110 msec and this prolongation was either disproportional to their sinus cycle length in some cases or fairly proportional to their long sinus cycle length in the other. It might be conceivable that changes in autonomic nervous tone in aged patients of group I influences both pacemaker automaticity of sinus node and conduction velocity within sinus node and/or perinodal fibers

to the same direction. Seipel et al,¹⁷⁾ however, did not find any relationship between SACT and heart rate. Reifel et al¹⁴⁾ and Seipel et al¹⁷⁾ reported in their studies of patients with sinus arrhythmia that SACT varied inversely with sinus cycle length.

Whatever the underlying electrophysiological mechanism may be, observation on the relation between SACT and basic sinus cycle length is of clinical importance. The normal range of SACT as the diagnostic parameter of sinus node dysfunction should be determined on the basis of understanding of the behavior of SACT in various physiological states, which is not available at the present time.

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