Comparison of Sinoatrial Conduction Time Measured by Holter method and Premature Stimulation Method

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Background: The reliability of noninvasive Holter method for the calculation of sinoatrial conduction time (SACT) has not been confirmed by results of invasive electrophysiological studies of sinus nodal function. The aim of this study was to compare the values of SACT obtained by Holter method with values estimated by premature atrial stimulation method.

Methods: The study population consisted of 61 patients, in whom the 24-hour ambulatory ECG monitoring had shown the occurrence of atrial premature beats. All these subjects were undergoing electrophysiological study including programmed atrial and ventricular stimulation. The measurements of SACT were obtained using spontaneous atrial premature beats (Holter method) and high right atrial stimulation (Strauss method).

Results: There was a good correlation between measurements of SACT by Holter method and Strauss method ($r = 0.79$; $P < 0.001$). There was no significant difference between values of SACT estimated by two compared methods. However, in certain patients, there were appreciable differences and SACT measured using spontaneous premature beats was shorter in 34 and longer in 23 patients than that estimated by the Strauss method. The values of SACT calculated by Holter method and Strauss method were significantly ($P < 0.001$) higher in patients with sick sinus syndrome than in those without evidence of sinus node dysfunction.

Conclusions: Good correlation between values of SACT obtained by two compared methods suggests that single measurement performed using Holter method may be adequate for reliable calculation of SACT.

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Holter ECG monitoring; programmed atrial stimulation; sick sinus syndrome; sinoatrial conduction time

The sinoatrial conduction time (SACT) is a measurement of the time from sinus node activation to local atrial activation in the region surrounding the sinus node. An abnormally long SACT indicates prolonged sinoatrial conduction and thus may be used to diagnose first-degree sinoatrial block. SACT is estimated commonly by means of two methods. The first was proposed by Strauss et al.¹ According to this method, SACT is estimated indirectly using premature atrial stimulation by subtracting basic sinus cycle length just before the atrial extrastimulus from the atrial return

cycle immediately after premature atrial beat. The second method introduced by Narula et al.² consists of continuous atrial pacing for eight beats at a frequency <10 bpm more than basic cycle sinus length. The SACT is calculated by subtracting the mean sinus cycle length from the interval between the last paced beat and the first sinus escape beat. Noninvasive Holter method³ for the estimation of SACT similarly as Strauss method is also based on premature atrial depolarization and reset of the sinus node; however, it utilizes spontaneous premature atrial beats instead of atrial

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extrastimuli coupling to sinus rhythm or atrial driving stimulation. The purpose of this study was: (1) to compare the results of noninvasive Holter method and invasive Strauss method for estimation of SACT and (2) to validate the hypothesis that Holter method may be applicable for simple and noninvasive calculation of SACT.

METHODS

The study population consisted of 61 patients (34 males and 27 females, mean age 57 ± 13 years) in whom the 24-hour ambulatory ECG monitoring had shown the occurrence of atrial premature beats that fulfilled the under mentioned criteria. All these subjects underwent a complete electrophysiological study for a variety of reasons. Fourteen patients presented with episodes of syncope or presyncope had evidence of sick sinus syndrome: nine had only symptomatic sinus bradycardia documented on 24-hour ECG monitoring, whereas five had overt sick sinus syndrome with sinus arrest or sinoatrial exit block. In the remaining 47 patients, the standard ECG as well as ambulatory monitoring showed no evidence of sinus pauses or symptomatic sinus bradycardia. Antiarrhythmic agents and digoxin had been discontinued for at least five drug half-lives before the study. Written informed consent from all patients was obtained before the electrophysiological testing.

Strauss Method

Programmed atrial stimulation of the high right atrium was performed using single premature beats delivered during sinus rhythm, starting from late diastole and decremented at 10 ms interval. The sinus escape intervals after the premature beats (A2-A3) were then plotted against the coupling interval of induced atrial beats (A1-A2). The SACT was calculated from the difference between mean length of the return cycles during rest responses (the last third of zone II) and basic sinus cycle length. To get a single conduction time the result was halved.

Holter Method

Ambulatory 24-hour ECGs were obtained using two-channel recorders, with bipolar leads CM5 (positive electrode in position V_5) and CM2 (positive electrode in position V_2). Measurements

Figure 1. Ladder diagram of the principle behind calculation of the SACT. SN = sinus node; SAJ = sinoatrial junction; A = atrium. P1-P1 = basic sinus cycle length; P2-P3 = return cycle length; A-S = retrograde SACT; S-A = anterograde SACT. Return cycle is the sum of the sinus cycle length plus retrograde and anterograde SACT.

were performed on the first fragment of Holter-ECG with premature atrial beats that fulfilled the following criteria:

- (1) The premature atrial depolarization with positive P wave in the lead CM5 occurred during normal daily activities at sinus rhythm rate 60–90 bpm.
- (2) The differences in cycle length between three consecutive PP intervals preceding premature atrial beats were lower than 20 ms.
- (3) The coupling interval of atrial premature depolarization was longer than 50% of the preceding sinus cycle length.
- (4) The sum of the coupling interval and the postextrasystolic pause was shorter than the sum of two spontaneous sinus cycles.

The following time intervals (Fig. 1) were estimated: (P1-P2)—the basic cycle length, i.e., the interval between the last two sinus P waves before the premature atrial beat; and (P2-P3)—the return cycle length, i.e., the interval between premature atrial beat and the next sinus P wave. The SACT was calculated according to the formula:

$$\text{SACT} = (\text{P2P3} - \text{P1P1})/2$$

Statistics

Continuous variables were expressed as mean $\pm$ SD. Student's test for paired and unpaired data was used for comparison. Linear regression analysis was used to assess the correlation between SACT values obtained by Holter method and Strauss method. Differences were taken to be significant at $P > 0.05$. For statistical calculations,

Table 1. Mean Sinoatrial Conduction Times in Evaluated Groups of Patients

	n	SACT (ms) Holter Method	SACT (ms) Strauss Method	P Value
Total group	61	126 ± 44	129 ± 43	0.3521
Patients with SSS	14	159 ± 52	165 ± 48	0.4166
Patients without SSS	47	116 ± 36	118 ± 35	0.5497

SACT = sinoatrial conduction time; SSS = sick sinus syndrome.

the package Complete Statistical System (Microsoft Corporation, Redmond, WA, USA) was used.

RESULTS

The mean values of SACT estimated by the two methods in the total group, as well as in patients with and without sick sinus syndrome, are listed in Table 1. There was no significant difference by this comparison in either group. The SACTs measured by Holter method were significantly longer ($P < 0.001$) in patients with sick sinus syndrome (mean 159 ± 52 ms) than in patients without sick sinus syndrome (mean 116 ± 36 ms). Similarly, the SACT values estimated by Strauss method were significantly longer ($P < 0.001$) in patients with than in those without sick sinus syndrome (165 ± 48 and 118 ± 35 ms, respectively).

There was a good correlation ($r = 0.79$, $P < 0.001$) between SACTs estimated by two compared methods (Fig. 2). However, the SACT measured using Holter method was shorter in 34 patients (mean 19 ms, range 1–60 ms) and longer in 23 persons (mean 20 ms, range 1–85 ms) than that estimated by the Strauss method. In the remaining four patients, both compared SACT values were identical. Figure 3 shows the distribution of the differences between measurements obtained using Holter method and Strauss method.

DISCUSSION

The concept that SACT could be inferred by noting the effects of premature atrial beats on the sinus rhythm was first proposed by Langendorf et al.⁴ in patients with atrial parasystole. This principle was applied to assess SACT using Holter method as well as by earlier introduced various electrophysiological tests. Several limitations should be taken into consideration when calculating the SACT using the foregoing methods. First, a premature atrial contraction can shorten

Figure 2. Correlation of the sinoatrial conduction time calculated by Holter method (SACT-Holter) and Strauss method (SACT-Strauss).

Figure 3. Percentage of patients in relation to three categories of the differences between values of sinoatrial conduction time calculated by Holter method and Strauss method.

the postreturn cycle by shortening the sinus node action potential by electronic interaction. Second, a zone II premature atrial contraction does not always capture the sinus node. Third, sinus node automaticity can be depressed by premature

atrial beat. The fourth assumption is that both anterograde and retrograde SACTs are not equal; retrograde SACT can be longer than anterograde SACT. Despite the foregoing limitations, a good correlation ($r = 0.78$) was found between SACT measured directly from sinus node electrogram and SACT estimated by indirect Strauss method.⁵

In this study, the measurement of SACT was based on any single atrial premature beat; therefore, one may question whether the Holter method is adequate for reliable SACT calculation due to autonomic influences on sinus node function. The autonomic nervous system has variable influence on the sinus node automaticity. The sympathetic hyperactivity produces an increase in the heart rhythm rate, while the predominance of the parasympathetic tone causes a decrease of the heart rate. In part, we have minimized this influence by selection of premature atrial beats recorded only at physiologic sinus rhythm rate; the normally innervated sinus node generates an impulse approximately 60 to 90 times per minute.⁶ In addition, previous study on the circadian rhythm of sinoatrial conduction velocity demonstrated similar values of SACT calculated by Holter method every 4 hours during normal daily activity; significant increase of SACT measurements was noted only at night.³

The site of the origin of spontaneous premature atrial beats has the influence on the calculation of SACT. The best stimulation point is the upper part of the right atrium or its appendage. Therefore, if spontaneous premature atrial beats are selected for calculation of SACT, the beats with positive P wave in lead CM5 should be preferred. However, in the absence of premature atrial beats with positive P wave, the atrial beats with negative P wave can also be used for SACT calculation. It was observed that a longer SACT is obtained (with a difference of 20 ms) when the bottom of the right atrium is stimulated.⁷ Furthermore, it was also reported that the values of SACT calculated using transoesophageal stimulation were similar to those obtained by the endocavitary method of right atrial stimulation.⁸ Thus, regardless of the P wave morphology of premature atrial beats, the SACT calculation using Holter method is probably accurate to about 10–20 ms.

Despite the limitations of the foregoing techniques, calculation of the SACT is a clinically useful tool. In the literature, the sensitivity of SACT measurements in patients with sinus node

dysfunction ranges from 54% to 75%; pooling findings from various studies permits a rough approximation of the sensitivity of SACT to be 62%.⁹ Some of the potential explanation for the variable sensitivity of SACT include: (1) the wide range of definition of normal values, (2) the different population studies, and (3) the different mechanisms of sinus node dysfunction, such as abnormal automaticity versus abnormal sinoatrial conduction. Breithardt et al.¹⁰ demonstrated, that the sensitivity of the SACT depends on the clinical and electrocardiographic presentation of patients. Subjects with asymptomatic sinus bradycardia or bradycardia-tachycardia syndrome did not have prolonged SACT, when compared to control group, but patients with symptomatic sinus bradycardia or sinoatrial block had abnormal measurements of SACT. Our observations that noninvasive measurements of SACT were significantly longer in patients with than in those without sick sinus syndrome suggest that calculation of SACT by Holter method can separate patients with sick sinus syndrome from those with normal sinus node function. Thus, in addition to the use of ambulatory ECG recordings for the confirmation of arrhythmias as the cause of symptoms occurring during daily activities, the calculation of SACT may be applied to the detection of sinus node function. Furthermore, in comparison with invasive electrophysiological tests, the Holter technique might also be used in analyzing the changes in sinoatrial conduction during a variety of physiologic states and pharmacologic interventions.

LIMITATIONS

Holter method is clearly inapplicable to patients without suitable atrial premature beats, but as the atrial arrhythmias are common in the general population, this limitation is of no practical consequence. In the study by Brodsky et al.,¹¹ 56% of normal male medical students had atrial premature beats. In the study of normal women, Sobotka et al.² reported atrial premature beats in 64% of subjects. Furthermore, the incidence of premature atrial beats increased with advanced age of patients and in patients with organic heart disease.

We also do not know whether the response to several atrial premature beats needs to be averaged as was the case in Strauss method, to

obtain a sensible measure of SACT. However, the good correlation between values of SACT obtained by two compared methods suggests that single measurement performed using Holter method may be adequate for reliable calculation of SACT.

In conclusion, Holter method for the calculation of SACT appears to be a promising technique to noninvasively assess sinus node function. In perspective, this simple approach could provide a useful tool for evaluating patients suspected or having sick sinus syndrome.

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