Observations of the Effect of Arrhythmias on the Cerebral Function by Recordings of 24-Hour Continuous Electrocardiograms

Comparison between the Sick Sinus Syndrome and Atrio-Ventricular Block

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SUMMARY

The influence of arrhythmias on cerebral function was investigated in 8 patients with sick sinus syndrome (bradycardia tachycardia syndrome) and 8 patients with advanced or complete atrio-ventricular block using 24-hour continuous recordings of the electrocardiogram and conventional electroencephalogram recordings. Syncope was observed more frequently in the atrio-ventricular block group, and was observed frequently when the longest heart beat pause during a 24-hour day was longer than 2.2 sec. Cerebral infarction as a complication of these arrhythmias was observed only with the sick sinus syndrome group. The maximum heart rate during a 24-hour day and the difference between maximum and minimum heart rate were significantly lower in the atrio-ventricular block group than in the sick sinus syndrome group. The electroencephalogram results showed a slight slowing of the background activity and the appearance of slow wave bursts in both groups. These abnormal findings were improved during intracardiac pacing in the atrio-ventricular block group. A quantitative analysis of the frequency of the electroencephalogram at various heart rates demonstrated the optimum pacing rate for the cerebral function. These results suggest that both the cerebral function and the cardiac function must be considered in the treatment of patients with bradycardia arrhythmias.

Additional Indexing Words:

Longest pause during a 24-hour day Syncope Cerebral infarction Slow wave burst Optimum pacing rate

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IT has been well known since the reports of Adams¹⁾ and Stokes²⁾ that a profound bradycardia or an ominous arrhythmia induces cerebral symptoms such as syncopal-convulsive episodes. Since the research on sick sinus syndrome of Ferrer³⁾ and Rubenstein et al,⁴⁾ both atrio-ventricular block and the sick sinus syndrome have been considered to be important arrhythmias that induce the Adams-Stokes attack. However, there have been no reports about differences in the effects of the sick sinus syndrome and atrio-ventricular block on the central nervous system. This paper has investigated the influence of cardiac arrhythmias on cerebral function particularly from the viewpoint of differences between the sick sinus syndrome and atrio-ventricular block.

SUBJECTS AND METHODS

Eight patients with the sick sinus syndrome (bradycardia tachycardia syndrome; i.e., group III in the classification by Rubenstein et al⁴⁾) and 8 patients with advanced or complete atrio-ventricular block were studied

Table I. Clinical Symptoms and 24-Hour Electrocardiographic Findings

Case	Age	Sex	Diagnosis	Dizzi- ness	Syncope	HR min	HR max	Longest Pause (sec)	Neurologic Disease
S.S.	52	M	SSS	+	-	32	64	1.69	Cerebral Infarction
M.K.	56	M	SSS	+	-	33	65	1.90	Cerebral Infarction
S.Y.	59	M	SSS	+	-	35	120	1.71	none
M.K.	65	M	SSS	+	+	45	94	2.40	none
Y.I.	68	M	SSS	+	-	36	75	2.14	none
H.N.	74	M	SSS	+	-	42	120	2.52	Cerebral Infarction
W.Y.	81	M	SSS	+	+	35	107	2.70	none
T.Y.	49	F	SSS	+	+	14	143	17.0	none
K.I.	60	M	Advanced AV Block	+	-	32	37	1.88	none
K.M.	76	M	Advanced AV Block	+	+	24	32	2.48	none
R.K.	82	M	Advanced AV Block	+	-	34	40	1.78	none
H.E.	19	F	Advanced AV Block	+	+	25	40	2.80	none
T.Y.	47	F	Advanced AV Block	+	+	26	88	2.72	none
A.N.	62	F	Complete AV Block	+	+	26	33	2.32	Park- insonism
M.N.	71	F	Advanced AV Block	+	+	37	98	48.0	none
T.I.	82	F	Complete AV Block	+	+	37	44	1.64	Dementia

AV Block=atrio-ventricular block; F=female; HRmax=the maximum heart rate per minute during a 24-hour day; HRmin=the minimum heart rate per minute during a 24-hour day; Longest Pause=the longest pause of heart beat during a 24-hour day; M=male; SSS=sick sinus syndrome.

(Table I). The ages ranged from 49 to 81 years (mean $\pm$ standard deviation; 63.0 ± 11.1 years) in the patients with the sick sinus syndrome, and from 19 to 82 years (mean $\pm$ standard deviation; 62.4 ± 21.2 years) in the patients with atrio-ventricular block. Twenty-four hour continuous electrocardiograms were recorded several times from each patient using the Holter Avionics system (Cardiocorder Model 400 or 450 and Electrocardioscanner Model 660A).^{5),6)} The longest pause, maximum heart rate and minimum heart rate were investigated using 24-hour electrocardiogram monitoring, as previously described.⁷⁾ The longest pause was defined as the longest R-R interval during a 24-hour day, which was obtained from the real time electrocardiograms. The maximum or minimum heart rate was defined as the maximum or minimum heart rate during a 24-hour day, which was obtained from the heart rate trendgram recordings and was ascertained by examining the real time electrocardiograms. In addition, Δ heart rate was defined as the difference between maximum and minimum heart rate.

The electroencephalogram was recorded from every patient using the International 10–20 system⁸⁾ or the electrode system of Gibbs and Gibbs.⁹⁾ This study was also made both in the bradycardia state and in the tachycardia state in 3 patients with the sick sinus syndrome, and it was performed with 4 patients with atrio-ventricular block before, and 2 or 3 months after the implantation of an intracardiac pacemaker. In addition, in 1 patient with advanced atrio-ventricular block, analyses of the frequency distribution in the electroencephalogram were made in the control state at a heart rate of 40 beats per minute (2:1 atrio-ventricular block) and at pacing rates of 50, 60, 70, 80, 90, and 100 beats per minute. In this case the effects of pacing strength (1.2, 2.0, 3.0, and 4.0 mA) on the electroencephalogram were also studied by the analysis of the frequency distribution of the electroencephalogram. These analyses were done using an ATTACK 2300 minicomputer system (Nihon Kohden). Student's t-test and the chi square test were also performed with this minicomputer.

RESULTS

Dizziness was observed in all patients in both the sick sinus syndrome group and the advanced or complete atrio-ventricular block group, but syncope was observed in 6 patients with atrio-ventricular block and in 3 patients with the sick sinus syndrome (Table I). Syncopal episodes were observed in 8 out of 9 patients, in whom the longest pause of heart beat during a 24-hour day was longer than 2.2 sec, and no syncopal episodes were observed in 6 out of 7 patients, in whom the longest pause was shorter than 2.2 sec. The

frequency of syncope was significantly larger in the group in which the longest pause was longer than 2.2 sec, according to statistical analysis using the chi square test ($p < 0.02$). The mean and standard deviation of the longest pause in patients with syncope was 9.12 ± 15.36 (1.64–48.0) sec and the longest pause in patients without syncope was 1.98 ± 0.27 (1.71–2.52) sec. However, the difference was not statistically significant. Although a significant difference was not observed in the minimum heart rate, the maximum heart rate during a 24-hour day differed significantly between the sick sinus syndrome and atrio-ventricular block groups ($p < 0.01$, Student's t-test). The mean and standard deviation of $\dot{J}$ heart rate was 63.6 ± 34.5 in the sick sinus syndrome group and 21.4 ± 25.0 in the atrio-ventricular block group. This difference was statistically significant ($p < 0.01$, Student's t-test).

Cerebral infarction due to cardiac arrhythmias was observed in 3 patients with the sick sinus syndrome, and Parkinsonism and dementia each appeared in 1 patient with atrio-ventricular block (Table I). The case of Parkinsonism was treated by artificial pacemaker implantation, and the signs and symptoms of Parkinsonism disappeared 2 or 3 months later.

Table II shows the electroencephalographic findings in patients with the sick sinus syndrome and atrio-ventricular block. In both groups the frequency of background activity in the electroencephalogram showed a tendency to be

Table II. The Electroencephalographic Findings

Case	Age	Sex	Diagnosis	Background Activity	Other Findings
S.S.	52	M	SSS	9-10	slow wave burst (5-6)
M.K.	56	M	SSS	diffuse α (8-9)	none
S.Y.	59	M	SSS	10	none
M.K.	65	M	SSS	9-10	slow wave burst (4-5)
Y.I.	68	M	SSS	9-10	slow wave burst (7)
H.N.	74	M	SSS	10	none
W.Y.	81	M	SSS	diffuse α (8-9)	none
T.Y.	49	F	SSS	9	none
K.I.	60	M	AV Block	9-10	slow wave burst (4-5)
K.M.	76	M	AV Block	diffuse α (8-9)	none
R.K.	82	M	AV Block	diffuse α (8-9)	slow wave burst (6-7)
H.E.	19	F	AV Block	9-10	slow wave burst (6-7)
T.Y.	47	F	AV Block	9-10	slow wave burst (3-6)
A.N.	62	F	AV Block	diffuse α (8-9)	slow wave burst (5-6)
M.N.	71	F	AV Block	diffuse α (8)	slow wave activity (6-7)
T.I.	82	F	AV Block	low voltage fast	none

The frequency of electroencephalogram is shown using the dimension of sec⁻¹.

AV Block=atrio-ventricular block; F=female; M=male; SSS=sick sinus syndrome.

Fig. 1. Slow wave burst in relation to the change of cardiac rhythm from paroxysmal supraventricular tachycardia to sinus bradycardia. This burst was recorded with the leads positioned at the frontal region. ECG = electrocardiogram; LC = left central lead; LF = left frontal lead; LO = left occipital lead; LT = left temporal lead; PSVT = paroxysmal supraventricular tachycardia; RC = right central lead; RF = right frontal lead; RO = right occipital lead; RT = right temporal lead; SSS = sick sinus syndrome.

slow. In the sick sinus syndrome group, diffuse α and slow α waves were observed as the background activity in 2 cases, and, in the atrio-ventricular block group, they were observed in 4 cases. In addition, slow wave bursts or slow wave activity, which appeared in relation to bradyarrhythmias, was observed in 3 patients with the sick sinus syndrome and in 6 patients with atrio-ventricular block. Fig. 1 shows an instance of slow wave bursts recorded with the leads positioned at the frontal region. This was observed during a change of cardiac rhythm from paroxysmal supraventricular tachycardia to sinus rhythm in a patient with the sick sinus syndrome (Case M.K.).

No qualitative differences could not be detected in 3 patients with the sick sinus syndrome between electroencephalographic findings measured during a state of sinus bradycardia and those measured during a state of tachyarrhythmia. Neither the background activity nor other findings in the electroencephalogram showed significant changes. On the other hand, when electroencephalographic findings from 4 patients with atrio-ventricular block were compared between the state of atrio-ventricular block and the state of cardiac pacing, some qualitative improvements were observed after the pacemaker therapy. Intracardiac pacing resulted in a decrease in the incidence of slow wave bursts in 2 cases.

Fig. 2. The effect of heart rate on the electroencephalogram findings in a case of advanced atrio-ventricular block (Case M.N.). The X axis shows a heart rate of 40, i.e., in the state of 2:1 atrio-ventricular block, and pacing rates of 50, 60, 70, 80, 90, and 100 beats per minute. The Y axis shows the percentage of α , β , and θ wave contents. The α and θ wave contents were the least in the state of 2:1 block and the greatest at a heart rate of 70 beats per minute. EEG=electroencephalogram; 2:1 block=2:1 atrio-ventricular block.

The relationship between heart rate and electroencephalographic findings was investigated quantitatively in a case of atrio-ventricular block (Case M.N.), as shown in Fig. 2. The background activity in the electroencephalogram in this case showed slow α wave activity, with the frequent appearance of slow wave activity. The α wave and θ wave contents were the least at a heart rate of 40, that is in the state of 2:1 atrio-ventricular block, and the greatest at a heart rate of 70. The β wave content was the greatest at a heart rate of 40 and the least at a heart rate of 70. The influence of pacing strength on the electroencephalogram was also analyzed. Contrary to the heart rate results, the α , β , and θ wave contents did not change in relation to the change of the strength of intracardiac pacing.

The diurnal distribution of the occurrence of syncopal-convulsive episodes in a patient with advanced atrio-ventricular block (Case M.N.) is shown in Fig. 3. In this case, syncope with convulsion appeared only during the daytime, except for two incidents during the night in relation to urination after postural changes. In other patients, syncopal-convulsive episodes appeared both during sleep and during the daytime, although the longest

Fig. 3. Diurnal distribution of syncope in a patient with advanced atrio-ventricular block (Case M.N.). Clock time is written around the circle and a shaded zone shows the nighttime and an open zone shows the daytime. Syncope appeared only during the daytime except for two occurrences during the night in relation to urination after postural changes.

Table III. Time and State of the Longest Pause during a 24-Hour Day

Case	Age	Sex	Diagnosis	Longest Pause (sec)	Time	State
S.S.	52	M	SSS	1.96	2:14 a.m.	sleep
M.K.	56	M	SSS	1.90	1:06 a.m.	sleep
S.Y.	59	M	SSS	1.71	4:09 a.m.	sleep
M.K.	65	M	SSS	2.40	5:18 a.m.	sleep
Y.I.	68	M	SSS	2.14	7:06 a.m.	sleep
H.N.	74	M	SSS	2.52	3:04 a.m.	sleep
W.Y.	81	M	SSS	2.70	6:48 a.m.	sleep
T.Y.	49	F	SSS	17.00	5:18 a.m.	sleep
K.I.	60	M	AV Block	1.88	4:22 a.m.	sleep
K.M.	76	M	AV Block	2.48	5:12 a.m.	sleep
R.K.	82	M	AV Block	1.78	3:57 a.m.	sleep
H.E.	19	F	AV Block	2.80	5:02 a.m.	sleep
T.Y.	47	F	AV Block	2.72	8:27 a.m.	postural change
A.N.	62	F	AV Block	2.32	3:46 a.m.	sleep
M.N.	71	F	AV Block	48.00	7:22 a.m.	postural change
T.I.	82	F	AV Block	1.64	2:12 a.m.	sleep

AV Block=atrio-ventricular block; F=female; Longest Pause=the longest pause of heart beat during a 24-hour day; M=male; postural change=a postural change from a supine to a standing position; SSS=sick sinus syndrome.

pause during a 24-hour day was observed during sleep (Table III). In a patient with the sick sinus syndrome (Case M.K.), the occurrence of paroxysmal supraventricular tachycardia with dizziness appeared frequently during the daytime in relation to a postural change from a supine to a standing position.

DISCUSSION

The results described in this study showed that bradycardiac arrhythmias induced cerebral symptoms and slight changes in the electroencephalogram. In addition, some differences were observed in the effects of arrhythmias on the central nervous system between the sick sinus syndrome and atrio-ventricular block. Dizziness was observed in all patients in both groups, but syncope was observed more frequently in the atrio-ventricular block group than in the sick sinus syndrome group. The difference in the length of the longest pause during a 24-hour day may be a cause of this difference, because the occurrence of syncope was observed frequently when the longest pause was longer than 2.2 sec and the number of such patients was greater in the atrio-ventricular block group than in the sick sinus syndrome group.

Bradyarrhythmias were thought to contribute to the occurrence of neurological diseases such as cerebral infarction, Parkinsonism and dementia. Cerebral infarction appeared only in the sick sinus syndrome group. This complication may be a consequence of the fact that changes in the cardiac rhythm were greater and more sudden in cases of the sick sinus syndrome than in cases of atrio-ventricular block. Namely, there were statistically significant differences in the maximum heart rate and Δ heart rate between the sick sinus syndrome and the atrio-ventricular block groups. On the other hand, Parkinsonism and dementia were observed only in cases of atrio-ventricular block. The occurrence of Parkinsonism, which had not yet been reported in the literature, was impressive because it appeared immediately after the occurrence of complete atrio-ventricular block from the normal sinus rhythm and it disappeared soon after the treatment of atrio-ventricular block by the pacemaker implantation.

The electroencephalographic results showed that there was a slight slowing of the cortical frequency as shown by the background activity and slow wave burst or slow wave activity in relation to a transient prominent bradycardia. The occurrence of abnormal findings in the electroencephalograms was more frequent in the atrio-ventricular block group than in the sick sinus syndrome group. Improvements in these abnormal features were not evident in the sick sinus syndrome patients when examined after an increase in the heart beat. On the other hand, in cases of atrio-ventricular block, some improvement was observed after pacemaker therapy, and a quantitative analysis of the frequency of the electroencephalogram demonstrated a relationship between heart rate and electroencephalogram findings. These results are consistent with the report of Sulg et al,¹⁰⁾ and a decrease in cerebral blood flow may be a cause of this slowing of the cortical frequency. In addition,

this result suggested that it is clinically important to investigate the optimum pacing rate in relation to both the cardiac function and the cerebral function, in order to prevent the pacemaker syndrome.

Syncopal-convulsive episodes appeared mainly during the daytime. Although they were not observed during the nighttime, the longest cardiac pause was observed frequently at night. The causes of this discrepancy between clinical symptoms and electrocardiographic abnormalities may be: 1) the possibility of a circadian rhythm in the susceptibility of the cerebral tissue to anoxia, 2) a decrease in the cerebral blood flow, related to a disorder in autonomic nerve reflexes during a postural change from the supine position to the standing position, 3) the occurrence of paroxysmal tachyarrhythmia and overdrive suppression after the postural change in the case of the sick sinus syndrome, and 4) the impossibility of detecting a syncope during the nighttime because of the sleep state.

The results obtained in the present study show a close relationship between cardiac function and the central nervous system. There have been many reports of electrocardiographic findings related to disorders of the central nervous system.^{11),13)} These reports suggest that the cerebral function as well as the cardiac function must be taken into account in the treatment of patients with arrhythmias.

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