AV Nodal Pathways in the R-R Interval Histogram of the 24-Hour Monitoring ECG in Patients with Atrial Fibrillation

Peter Weismüller, M.D., Caroline Kratz, Bodo Brandts, M.D.,
Klaus Kattenbeck, M.D., Hans-Joachim Trappe, M.D.,
and Carsten Ranke, M.D.

From the Marienhospital, University of Bochum, Germany

Background: Patients with more than one AV nodal pathway show two and more peaks in the histogram of the R-R intervals of the Holter monitoring ECG during atrial fibrillation. It was the purpose of the present study to determine the number of patients showing more than one AV nodal pathway in a larger patient group with permanent atrial fibrillation by analyzing the Holter monitoring ECG.

Methods: 250 patients with permanent atrial fibrillation during Holter monitoring ECG were studied; 203 patients had structural heart disease. The number of peaks in the R-R interval histogram of each patient was determined. The distribution of the number of peaks in the R-R interval histogram in different patient groups was analyzed.

Results: 153 patients (61%) had one peak, 80 patients (32%) two peaks, 13 patients (5%) three peaks, and four patients (2%) four peaks, reflecting the number of different AV nodal pathways. In the different patient groups, in the patients with or without structural heart disease, with coronary heart disease, with a history of syncope, and in patients with a mean heart rate of more than 100/min, there was no significant difference in the distribution of the number of peaks in the R-R interval histogram.

Conclusions: In more than one third of all patients with permanent atrial fibrillation there are two, three, or four AV nodal pathways. It is suggested that this number of different AV nodal pathways found in the studied group can be applied to all humans. 38.8% of all patients with permanent atrial fibrillation have more than one AV nodal pathway; 6.4% of all patients with atrial fibrillation would benefit from an ablation of AV nodal pathways with shorter refractory periods for reduction of the heart rate.

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AV nodal pathway; R-R interval histogram

AV nodal reentrant tachycardia is the most common regular supraventricular tachycardia in humans and comes to 60% of all regular supraventricular tachycardias.¹ However, the incidence of multiple AV nodal pathways in patients without AV nodal reentrant tachycardia undergoing an electrophysiological study for other reasons ranges between 10%² and 35% in children.³ The presence of multiple AV nodal conduction pathways can be detected in patients

with atrial fibrillation noninvasively by analyzing the R-R interval histogram in the 24-hour Holter monitoring ECG, in which more than one peak in the R-R interval histogram is visible.⁴ Thus, the purpose of this study was to determine the number of individuals with more than one AV nodal pathway in a larger cohort of patients with permanent atrial fibrillation by analyzing the peaks of the R-R interval histogram of the Holter monitoring ECG.

Address for reprints: Peter Weismüller, M.D., Department of Cardiology and Angiology, Marienhospital, University of Bochum, Hölkeskampring 40, 44625 Herne, Germany. Fax: 02323-499-360; E-mail: Peter.Weismueller@ruhr-uni-bochum.de

METHODS

Two hundred and fifty consecutive patients with permanent atrial fibrillation during a 24-hour Holter monitoring electrocardiogram were studied retrospectively. There were 124 males and 126 females with a mean age of 71 ± 9 years (36 - 88 years). Forty seven patients (38.8%) had no structural heart disease. In 203 patients (81.2%) structural heart disease was present. In 82 patients (32.8%) significant coronary artery disease was confirmed by coronary angiography, 45 patients (18.0%) had suffered a prior myocardial infarction. One hundred ten patients (44.0%) had arterial hypertension. In 33 patients, (13.2%) dilative cardiomyopathy was present. Sixty-three patients (25.2%) had valvular heart disease and one patient (0.4%) reported a history of rheumatic fever. Seventeen patients (6.8%) had a history of syncope. Two hundred patients (80.0%) received drugs for rate control (digitalis, calcium antagonists, beta blocking agents). The R-R interval histogram of the Holter monitoring ECG (Elatec 300 E; Ela, Munich, Germany) of each patient was analyzed. All R-R intervals within an interval of 10 ms were added. The number of peaks in the R-R interval histogram of each patient was visually determined and counted. Different subgroups of patients were analyzed: all 250 patients, 47 patients without structural heart disease, 203 patients with structural heart disease, 82 patients with significant coronary artery disease, 121 patients with other structural heart disease, 17 patients with syncope, and 36 patients with a mean heart rate of more than 100/min in the Holter monitoring ECG.

Statistics

The different patient groups were analyzed using the Chi-square test. A P value of ≤ 0.05 was considered significant.

RESULTS

The mean heart rate of all patients was 83.0 ± 17.0 /min (48 - 163/min) which means a mean interval of 751.8 ± 147.3 ms (1257 - 368 ms). In 97

patients (38.8% of all patients) two, three, or four peaks were found in the Holter recording (Fig. 1).

One Peak in R-R Interval Histogram

In 153 patients (61.2% of all patients) the R-R interval histogram showed one peak, representing one AV nodal pathway. The mean heart rate was 83.9 ± 16.5 /min (53 - 163/min), which corresponds to a mean R-R interval of 739.6 ± 130.1 ms (1140 - 368 ms).

Two Peaks in R-R Interval Histogram

For the 80 patients (32.0%) in whom two peaks were found, the mean heart rate was 82.1 ± 17.0 /min (48 - 128/min) and a mean R-R interval of 763.2 ± 164.7 ms (1257 - 468 ms).

Three Peaks in R-R Interval Histogram

In thirteen of the patients (5.2% of all patients), three peaks in the R-R interval histogram could be identified. The mean heart rate of these patients was 83.2 ± 21.4 /min (52 - 127/min), the mean R-R interval was 770.3 ± 195.4 ms (1164 - 471 ms).

Four Peaks in R-R Interval Histogram

In four patients (1.6% of all patients) four different peaks were found in the R-R interval histogram. The mean heart rate was 64.8 ± 1.8 /min (63 - 67/min), and the mean R-R interval was 927.8 ± 29.3 ms (956 - 891 ms).

Analysis of the Different Patient Groups

The characteristics of different patient groups are shown in Table 1. The groups had no significant difference regarding age, mean heart rate, and mean R-R interval, except the patient group with a rate of more than 100/min. The number of patients with one, two, three, and four different peaks in the R-R interval histogram was determined (Table 1). There was no statistical difference between the groups found in the distribution of the number of multiple peaks in the R-R interval histogram.

Patients with Mean Heart Rate of ≥ 100 /min in Holter Monitoring ECG

In 36 patients the mean heart rate was ≥ 100 /min. Fifteen patients (42%) complained of symp-

Figure 1. Shown are examples of the four different patterns of the R-R interval distribution in the R-R interval histograms of the Holter monitor ECGs. Upper left: A patient with one AV nodal pathway. Upper right: A patient with two AV nodal pathways. Lower left: A patient with three AV nodal pathways. Lower right: A patient with four AV nodal pathways. X-axis: R-R interval (ms); y-axis: number of R-R intervals.

toms attributable to rapid atrial fibrillation. Only one patient had a history of syncope. Twenty-eight patients (77.8%) exhibited structural heart disease. Twenty-eight percent of the patients received drugs for rate control. These relative numbers are not statistically different from the characteristics of the whole patient group.

Influence of Drugs on Number of Peaks in R-R Interval Histogram

To analyze the effect of drugs on the number of peaks in the R-R interval, the number and distribution of the patients taking drugs, taking no drugs, and taking digitalis were analyzed. As seen in Table 2, there is no significant difference in the number and distribution of the peaks in the R-R interval of the different patient groups.

DISCUSSION

The presence of more than one peak in the R-R interval histogram of patients with atrial fibrillation is well known.⁵ Dual AV nodal physiology was considered to be the underlying mechanism. Rokas et al.⁴ proved this in a series of 38 patients with chronic atrial fibrillation. They determined the AV nodal conduction physiology during an electrophysiological study after cardioversion to sinus rhythm. Dual AV node physiology was found in 42% of their patients. The sensitivity and specificity of the R-R interval histogram indicating the presence of dual atrioventricular node physiology was 88 and 80%, respectively. Tebbenjohanns⁶ investigated 37 patients with uncontrolled ventricular rate during atrial fibrillation before ablation of the slow conducting AV nodal pathway for rate

Table 1. Clinical Characteristics and Number of Peaks in All Patients and in Different Patient Groups

	All Patients	Without Structural Heart Disease	With Structural Heart Disease	CAD	Other Structural Heart Disease	Syncope	Mean Heart Rate > 100 min ⁻¹
Number of patients	250	47	203	82	121	17	36
Male	124 (50%)	22 (47%)	104 (51%)	51 (62%)	53 (44%)	6 (35%)	20 (56%)
Age (years)	71 ± 9	74 ± 10	70 ± 9	72 ± 8	69 ± 10	72 ± 9	69 ± 11
Mean heart rate (min ⁻¹)	83 ± 17	85 ± 20	83 ± 15	81 ± 14	83 ± 17	82 ± 10	112 ± 14
Mean R-R interval (ms)	751 ± 147	706 ± 135	727 ± 140	638 ± 111	722 ± 157	640 ± 114	542 ± 58
Patients with 1 peak	153 (61%)	30 (64%)	122 (60%)	49 (60%)	73 (60%)	11 (64%)	20 (56%)
Patients with 2 peaks	80 (32%)	11 (23%)	70 (35%)	26 (32%)	44 (36%)	5 (29%)	13 (36%)
Patients with 3 peaks	13 (5%)	5 (11%)	8 (4%)	6 (7%)	2 (2%)	1 (6%)	3 (8%)
Patients with 4 peaks	4 (2%)	1 (2%)	3 (2%)	1 (1%)	2 (2%)	0 (0%)	0 (0%)

CAD: coronary artery disease; ms: milliseconds; no.: number; pts.: patients.

control. Twenty-two of the 37 patients showed two peaks in the R-R interval histogram. In 17 patients (77%), dual AV node physiology was found during an electrophysiologic study in sinus rhythm. In the other 15 patients with one peak in the R-R interval histogram, only two patients showed dual AV node physiology during an electrophysiologic study. Thus, the finding of more than one peak in the R-R interval histogram of the patients with atrial fibrillation reflects the presence of multiple AV nodal pathways. The correlation between the number of peaks in the R-R interval histogram and the number of AV nodal pathways is not 1/1.^{4,6} This may be due to autonomic influences, since adrenergic and vagal activity may lead to changes in R-R intervals, if a longer recording period is analyzed. In addition, the presence of two AV nodal pathways may

not be detected by an electrophysiologic study.⁷ However, this may only lead to a small inaccuracy in the determination of the number of multiple AV nodal pathways by counting the number of peaks in the R-R interval histogram.⁶

In the literature, there are only few studies with high numbers of patients with dual AV nodal physiology investigated by an electrophysiological study with an indication other than AV nodal reentrant tachycardia. The number of patients with dual AV nodal physiology reported is between 6% in 397 patients² and 35% of 78 patients.³ In our study, a large number of patients with permanent atrial fibrillation was studied by analyzing the Holter monitoring ECG. One main finding of our study was the high incidence of multiple AV nodal pathways in patients with atrial fibrillation with an

Table 2. Clinical Characteristics and Number of Peaks in All Patients, in Patient Groups without Antiarrhythmic Drugs, with Antiarrhythmic Drugs and with Digitalis

	All Patients	Without Drugs	With Drugs	With Digitalis
Number of patients	250	50	200	155
Male	124 (50%)	28 (56%)	96 (48%)	71 (46%)
Age (years)	71 ± 9	70 ± 8	71 ± 9	72 ± 9
Mean heart rate (min ⁻¹)	83 ± 17	84 ± 19	83 ± 17	82 ± 15
Mean R-R interval (ms)	751 ± 147	722 ± 133	753 ± 143	755 ± 136
No. pts. with 1 peak	153 (61%)	31 (62%)	126 (63%)	90 (58%)
No. pts. with 2 peaks	80 (32%)	15 (30%)	62 (31%)	55 (32%)
No. pts. with 3 peaks	13 (5%)	4 (8%)	8 (4%)	8 (5%)
No. pts. with 4 peaks	4 (2%)	0 (0%)	4 (2%)	2 (1%)

Abbreviations: see table 1.

incidence of 38.8%. Ebert⁸ found a lower rate of multiple R-R interval peaks with 22.5% in 197 patients with atrial fibrillation.

Another important finding of our study was the detection of more than two peaks in 17 out of 250 patients, i.e., 6.8% of all patients, 13 patients had three peaks (5.2%) and 4 patients (1.6%) had four peaks. In the series of Rokas⁴ with 38 patients, they only found one patient (2.6%) with three peaks in the R-R interval histogram. In this patient, three AV nodal pathways were detected during the electrophysiologic investigation in sinus rhythm. Ebert⁸ reported two peaks in 20% of his patients, and 2.5% showed three peaks. The presence of four peaks in the R-R interval histogram in patients with atrial fibrillation is not mentioned in the literature. However, this finding is not unexpected, since in AV nodal reentrant tachycardia the presence of more than two AV nodal pathways is well known. Tai et al.⁹ reported three AV nodal pathways in 21 patients (4.2%) and four AV nodal pathways in four patients (0.8%) out of 500 patients with AV nodal reentrant tachycardia, i.e., patients who have at least two AV nodal pathways. In our series of patients with AV nodal reentrant tachycardia,¹⁰ we found the presence of three AV nodal pathways, in 29 patients (33.7%). Four of 86 patients had four AV nodal pathways (4.7%) during an electrophysiological study of patients with AV nodal reentrant tachycardia. In the present study, the number of patients with three peaks in the R-R interval histogram was 13 (14.0%) and there were four patients with four peaks (4.3%) out of 93 patients with more than one peak in the R-R interval histogram. Thus, the presence of more than two AV nodal pathways is not an uncommon finding. The numbers of two, three, and four peaks in the R-R interval histogram in the different patient groups analyzed in our study is not significantly different. This confirms the suggestion that the conduction via the different AV nodal pathways is not significantly influenced by alterations due to the acquired disease.

The influence of drugs taken during the Holter monitoring ECG recording which may influence the number of R-R interval peaks does not seem to change the results, since there was no significant

difference found in the number of R-R interval peaks between the patients with and without drugs.

CONCLUSIONS

Nearly 40 % of all patients with permanent atrial fibrillation give evidence to have more than one antegrade conducting AV nodal pathway. It is suggested, that this number of different AV nodal pathways found in the studied group of patients with atrial fibrillation is applicable to all humans. This high incidence of multiple AV nodal pathways is in concordance with the high incidence of AV nodal reentrant tachycardias.

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