Mechanism and Prediction of Sudden Cardiac Death in Arrhythmia Patients Using Electrophysiological Studies

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Thirty nine cases, in which sudden cardiac death (SCD) was suspected, were studied to evaluate the mechanism and the prediction of SCD in arrhythmia-patients using electrophysiological studies (EPS). The 39 cases (28 male and 11 female) were located by surveying 2098 patients who underwent EPS for the evaluation of arrhythmias. Age at time of EPS ranged from 4 to 86 years, average 50.5 years. Time from EPS to death was 2 to 163 months, average 27.9 months. Underlying heart disease was: dilated cardiomyopathy in 11, old myocardial infarction in 5, ischemic heart disease in 5, hypertensive heart disease in 5, valvular heart disease in 3, hypertrophic cardiomyopathy in 2, arrhythmogenic right ventricular dysplasia in 1, myocarditis in 1, sarcoidosis in 1, cor pulmonale in 1, and no obvious heart disease in 4. Fifteen had a permanent pacemaker implanted.

SCD in cases without a permanent pacemaker (24 cases): 2 had chronic complete A-V block (one BH block, one HV block), 1 had advanced A-V block (HV block), 3 had bundle branch block with first degree HV block, 9 had ventricular tachycardia (VT), 3 had sick sinus syndrome (SSS), 3 had paroxysmal atrial flutter, 1 had WPW syndrome and paroxysmal atrial fibrillation, 1 had paroxysmal atrial tachycardia, and 3 had premature ventricular beats and first degree HV block.

SCD in cases with permanent pacemaker (15 cases): 5 had SSS, and 10 had A-V block. In 3 of the 5 with SSS and 7 of the 10 with A-V block, VT was found before pacemaker implantation.

In our study, brady and tachyarrhythmias coexisted in 25 cases (64%). Twenty two of these were ventricular arrhythmias. Therefore, the coexistence of bradyarrhythmias with ventricular arrhythmia (especially VT), and the treatment of VT as well as bradyarrhythmias are thought to have great clinical importance.

ARRHYTHMIAS are one of the most important causes of sudden cardiac death (SCD). Arrhythmia-related transient cerebral ischemia, accompanied by symptoms of faintness and syncope called Adams-Stokes (AS) attacks, may

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ultimately result in sudden death, but the phenomenon is still not fully understood. Diagnosis and treatment of arrhythmias has made great strides in recent years with the advancement of electrophysiological studies (EPS). The utility of EPS in pacemaker and antiarrhythmic therapy has become widely recognized.¹⁻⁵ However, the utility of EPS in the prediction of SCD and the determination of its mechanism is yet unclear.

The purpose of this study is to evaluate the mechanism and prediction of arrhythmia-related

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Fig.1. Sudden cardiac death in cases without permanent pacemaker. A-V b1: A-V block, SSS: sick sinus syndrome, VT: ventricular tachycardia, Chr.III: chronic complete A-V block, adv A-V b1: advanced A-V block, BBB: bundle branch block, PAF: paroxysmal atrial flutter, PAT: paroxysmal atrial tachycardia, I°HV b1: first degree HV block, HHD: hypertensive heart disease, OMI: old myocardial infarction, VHD: valvular heart disease, Cor pulm: cor pulmonale, DCM: dilated cardiomyopathy, ARVD: arrhythmogenic right ventricular dysplasia, HCM: hypertrophic cardiomyopathy, IHD: ischemic heart disease.

sudden death by analyzing the clinical features, ECGs, EPS findings, underlying heart disease, and treatment of SCD victims who had undergone EPS.

MATERIALS AND METHODS

Subjects consisted of 39 cases in which SCD was suspected. The 39 cases were located by surveying 2098 patients who underwent EPS for the evaluation of arrhythmias. SCD was defined as unexpected death within 24 hours of deterioration in the patient's condition, and where the involvement of arrhythmias was strongly suspected. Any death attributable to another cause (eg. myocardial infarction) was excluded.

RESULTS

I. Clinical features: The 39 subjects consisted of 28 males and 11 females. Age at time of EPS ranged from 4 to 86 years, average 50.5 years. Time from EPS to death was 2 to 163 months, average 27.9 months. Patient ar-

rhythmias were as follows: 8 had sick sinus syndrome (SSS), 16 had A-V block, 19 had ventricular tachycardia (VT), 2 had WPW syndrome, 3 had paroxysmal atrial flutter, 3 had premature ventricular beat, and one had paroxysmal atrial tachycardia. Twenty five had both bradyarrhythmias and tachyarrhythmias. Underlying heart disease was: dilated cardiomyopathy in 11, myocardial infarction in 5, ischemic heart disease in 5, hypertensive heart disease in 5, valvular disease in 3, hypertrophic cardiomyopathy in 2, arrhythmogenic right ventricular dysplasia in 1, myocarditis in 1, sarcoidosis in 1, cor pulmonale in 1, and no obvious heart disease in 4. Fifteen had permanent pacemakers implanted.

II. SCD in cases without permanent pacemaker (Fig. 1): Two had chronic complete A-V block (one BH block, one HV block), 1 had advanced A-V block (HV block), 3 had bundle branch block with the prolongation of HV interval block. None had any history of Adams-Stokes attacks. All had underlying heart disease. Nine had VT and 3 received antiarrhythmic agents. In terms of underlying heart disease, 3 had myocardial infarction, 2 had dilated

Fig. 2. Sudden cardiac death in cases with permanent pacemaker.

TABLE I INCIDENCE OF BRADY-TACHY ARRHYTHMIAS

Atrial arrhythmia	Ventricular arrhythmia	Cases without pacemaker	Cases without pacemaker	Total
tachy*		2	0	2
brady**		1	0	1
	tachy***	5	0	5
	brady****	4	2	6
tachy-brady		1	1	2
	tachy-brady	6	5	11
brady	tachy	0	1	1
tachy	brady	1	0	1
tachy	tachy-brady	2	3	5
tachy-brady	tachy	2	2	4
tachy-brady	tachy-brady	0	1	1

*Include premature atrial beat, atrial tachycardia, atrial flutter, atrial fibrillation. **Include SA block, sinus arrest, sinus bradycardia. ***Include premature ventricular beat, ventricular tachycardia, ventricular fibrillation. ****Include A-V block, bundle branch block.

cardiomyopathy, 1 had arrhythmogenic right ventricular dysplasia, 1 had hypertensive heart disease, and 2 had no obvious heart disease. In 2 of the 9 cases VT was associated with SSS. Three had paroxysmal atrial flutter (PAF), variously associated with hypertrophic cardiomyopathy, aortic stenosis, and myocarditis. In one of these cases rapid ventricular response with intraventricular aberrant conduction was found. In the other 2, accelerated A-V nodal function was found during EPS. One case with WPW syndrome had valvular disease and parox-

ysmal atrial fibrillation (so-called pseudo VT). Three cases had dilated cardiomyopathy, premature ventricular beats, and first degree HV block.

III. SCD in cases with permanent pacemakers (Fig. 2): Fifteen of the subjects had permanent pacemakers. Five of these had SSS and 10 had A-V block. In 3 of the 5 with SSS and 7 of the 10 with A-V block, VT was found before pacemaker implantation, and only 3 of these were receiving antiarrhythmic agents for the VT. One case with SSS had WPW syndrome and

paroxysmal atrial fibrillation as well. Underlying heart disease was found in 14. Of these, 5 had dilated cardiomyopathy, 2 had old myocardial infarction, 4 had ischemic heart disease, 1 had hypertrophic cardiomyopathy, 1 had valvular heart disease and 1 had sarcoidosis.

IV. Brady-tachyarrhythmias (Table I): Seven of the 39 cases (18%) had only tachyarrhythmias. Five of these were ventricular and 2 were atrial. None had pacemakers but all received antiarrhythmic agents orally. Seven cases (18%) had only bradyarrhythmias, of which 5 were without pacemakers. Brady and tachyarrhythmias coexisted in 25 cases (64%). Twenty two of these were ventricular arrhythmia, of which 17 had A-V block, 6 had SSS, and 13 had pacemakers. In the 3 cases without ventricular tachyarrhythmias, 2 had brady-tachy syndrome and the other had complete A-V block with atrial fibrillation.

DISCUSSION

EPS is widely used to identify arrhythmia, analyse its mechanism and severity, and help in selection of treatment, including antiarrhythmic drug and pacemaker therapy. However, there are few long-term follow-up studies of patients whose treatment is determined by EPS. It is therefore important to assess the usefulness and limitations of EPS in the prediction and prevention of SCD.

We used questionnaires to survey 2098 patients who received EPS, and located 39 cases (2%) in which arrhythmia-related SCD was suspected from 1771 responses. Considering that the survey population all had arrhythmias severe enough to warrant EPS in the first place, this SCD incidence rate seems quite low. Perhaps EPS contributed to the selection of proper treatment in many cases, but it may also be that the figures were skewed by an insufficient response rate and our strict definition of SCD. Since SCD was defined as unexpected death most probably due to arrhythmias and which occurred within 24 hours, and omitted other causes such as acute myocardial infarction, the determination of SCD differed somewhat by respondent.^{6,7}

Sick sinus syndrome: At the present time, the natural history of SSS is unknown.^{8,9} The mortality does not appear to be significantly influenced by the presence of a permanent pacemaker. Of the 8 patients with SSS in this study, 5 had pacemakers. Death in SSS with a

permanent pacemaker most frequently results from complications of associated cardiovascular disease or cerebrovascular disease. In our study, since all 5 had underlying heart disease, and 3 had VT before pacemaker implantation, ventricular fibrillation (VF) could be suspected as the cause of death. The 3 without pacemakers had no history of Adams-Stokes attacks and sinus node dysfunction was only mild at the time of EPS, but 2 had underlying heart disease and VT, so VF was also suspected. In all 5 cases with VT, the antiarrhythmic drug therapy they received seemed insufficient. The presence of underlying heart disease and/or VT significantly affects the follow-up of SSS patients, and should be carefully considered in the selection of antiarrhythmic drug therapy.

A-V block: The prognosis of A-V block patients with pacemakers is said to depend on underlying heart disease. We have previously reported on the importance of VT presence or absence before and after pacemaker implantation.¹⁰ In this study, VT was present before pacemaker implant in 7 of the 10 cases. Seven had underlying heart disease and received no medication for VT. Therefore patient death was thought to result from VF related to VT. It is our opinion that VT evaluation and treatment with antiarrhythmic agents where it is present should be required in patients with A-V block.

Generally, a history of Adams-Stokes attacks is an important indication for pacemaker implantation, but in the present study all 6 cases without permanent pacemakers had no history of Adams-Stokes attacks. Therefore it is important to note that SCD can occur in cases of A-V block without any history of Adams-Stokes attacks. In 2 of the above 6 cases SCD was thought to be caused by ventricular asystole due to block in block, and paroxysmal A-V block was suspected in the other 4 cases with advanced A-V block or bundle branch block. Although patients with complete A-V block who are asymptomatic receive a permanent pacemaker when the ventricular rate is less 40/min,¹¹ our studies indicate that pacemaker implantation should be recommended in cases of complete BH or HV block even when ventricular rate is over 50/min. Dhingra and coworkers reported that asymptomatic patients who develop bundle branch block with no obvious disease are likely to have good prognosis, even when HV intervals are significantly prolonged.¹² However, the 2 above cases were suggested to indicate a preventive pacemaker im-

plant due to the presence of HV interval prolongation.

Ventricular tachyarrhythmia: VT is a serious arrhythmia, but its clinical significance varies widely. In this study, VT was found in 19 of the 39 cases. Ten of these also had A-V block or SSS, for which pacemakers were implanted. Only 3 of these received antiarrhythmic agents. One of the pacemaker recipients and 9 others without bradyarrhythmias received antiarrhythmic agents chosen with EPS. The fact that all patients suffered SCD in spite of this suggests the limitations of antiarrhythmic drug therapy against VT. Few controlled data are available concerning the role of antiarrhythmic treatment for the prevention of sudden death.¹³ Further experience, especially long-term follow-up, is required. Furthermore, of the 19 cases with VT, 2 had no obvious heart disease. Although the prognosis of idiopathic VT is thought to be good, it should be carefully monitored and surgical treatment should not be ruled out when it is accompanied by faintness or syncope.

Paroxysmal atrial flutter: PAF is likely to occur in cases with Adams-Stokes attacks when 1:1 A-V conduction exists or when congestive heart disease is present. The 3 cases of PAF in this study all had underlying heart disease and accelerated A-V nodal conduction. Therefore hemodynamic deterioration or ventricular fibrillation due to 1:1 A-V conduction is suspected as the cause of SCD. Accordingly, the evaluation of A-V conduction and the influence of drugs on it is thought to be important.

WPW syndrome: Recent reports suggest that WPW syndrome with paroxysmal atrial fibrillation and shorter refractory of the accessory pathways poses high risk for SCD.¹⁴ Since progression of pseudo-VT to ventricular fibrillation might be suspected as the cause of SCD in the 2 cases with WPW syndrome in this study, they support the high risk categorization.

Brady-tachyarrhythmias: Brady-tachy syndrome is a form of SSS which has sinus node dysfunction associated with paroxysmal atrial fibrillation, atrial flutter, supraventricular tachycardia, and/or rarely VT. Kaplan et al indicated that atrial muscle as well as the sinus node is involved in the brady-tachy syndrome.¹⁵ In the present study it is noteworthy that 5 of the 7 cases with brady-tachy syndrome also had VT. Consequently, the impairment of ventricular muscle, even though it may be rare, is thought to be clinically important in this syndrome. The

fact that VT was found in 7 of the 10 cases with A-V block also suggests the involvement of damaged ventricular muscle along with special conduction system impairment. Therefore the coexistence of bradyarrhythmias with ventricular tachyarrhythmias (especially VT), and the treatment of VT as well as bradyarrhythmias are both thought to have great clinical importance.

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