Sudden Cardiac Death in Japanese People Aged 20–60 Years — An Autopsy Study of 133 Cases —

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In order to elucidate the principal cause and actual circumstances of sudden cardiac death in Japan, especially among people in the prime of life, we investigated 133 out of 161 autopsied patients (82.6%) (106 men and 27 women, mean age 47.5 years). Coronary artery disease (CAD) was the most frequently detected disorder (50 cases, 37.6%), and included 15 cases of acute myocardial infarction (AMI) (11.3%). We found that CAD was less frequent among younger patients than in Western countries: 10.0% in subjects in their twenties and 22.2% among subjects in their thirties. The left anterior descending artery (LAD) was the vessel most often affected by infarction (47.0%), but the proportion of LAD lesions was not different from that in AMI patients who were survived for least 1 day after the attack. In conclusion, CAD was infrequent among patients aged 20–39 years in comparison with Western countries and LAD was the most commonly affected vessel, but the proportion was not different from that found among AMI patients who survived for at least 1 day after the attack.

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Key Words: Sudden cardiac death; Coronary artery disease; Acute myocardial infarction

Sudden cardiac death occurring among subjects in the prime of life is currently a major social and medical problem faced by practitioners. How to prevent premature death in young people needs to be resolved urgently. However, despite great past efforts, the principal cause and actual circumstances of sudden cardiac death remain obscure, especially in younger people, who do not usually exhibit any clinical features of unexpected cardiac death. A population survey of official death certificates conducted by Hayashi et al¹ revealed that the proportion of sudden cardiac deaths of unknown cause is significantly higher in young people (aged 15–50 years) than in the elderly of both sexes, reaching 67.8% in younger male victims and 51.1% in female victims.

We identified pathologically the main cause of cardiac death in autopsied cases. In addition, histories were collected from relatives and friends by interviews and questionnaires. We focused on pathologic findings

in coronary arteries. Several characteristics of immature cardiac death were highlighted and compared with those reported from Western countries.

Subjects and Methods

From May 1994 to May 1996, patients who died suddenly of natural causes and who were autopsied in the Department of Forensic Medicine, Kitasato University School of Medicine, were selected as possible subjects of sudden death according to the following criterion: death within 24 h of the onset of acute illness. We defined sudden cardiac death as sudden death whose cause was proved at necropsy to be cardiac or assumed to be cardiac because of clinical circumstances in accordance with Madsen's definition². Furthermore, we focused on those who died of coronary artery disease unexpectedly in the prime of life (20–60 years of age). Also, subjects who were thought to have died

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abruptly and who were discovered within 3 days of death were enrolled in the present study. The assumption that a person had died within 24 h of the onset of acute symptoms or signs was based on, for example, neighbors' testimony or newspapers accumulating since the day after the victims had been known to be alive. Deaths among residents of nursing homes were not counted as sudden deaths. Residence of the victims was limited to Sagami-hara City and its surrounding areas. The population of these districts was 5,757,627 as of 1 July 1996. During the previous 25 months, 161 patients in the 20–60 year age group were enrolled in this study out of a total of 483 cases of sudden death. Out of these potential study cases, 133 patients were autopsied having received judicial permission or consensus from the victims' relatives (an autopsy rate of 82.6%). The subjects' mean age was 47.5 years (106 men and 27 women). A total of 96 out of the 133 patients (72.2%) were brought to the Emergency and Critical Care Center of Kitasato University Hospital by ambulance and died. The main causes of death were identified only by pathologic findings. Their histories were as far as possible collected from families and friends by interviews and questionnaires.

We examined the 4 main epicardial coronary arteries (the left main, left anterior descending, left circumflex, and right coronary arteries) by cutting at 0.5-cm intervals to their distal tributaries. Death due mainly to coronary artery disease (CAD) was defined as follows. Firstly, there was no other apparent cause of natural death. Secondly, the death should satisfy at least 1 of the following criteria: (1) macroscopic documentation of coronary artery narrowing involving more than 75% of the cross-sectional area; (2) the presence of old myocardial infarction; or (3) obvious evidence of acute myocardial infarction (AMI). AMI was diagnosed on the basis of fresh myocardial necrosis with or without coronary arterial obstruction by fresh thrombus or intimal edema in accordance with Roberts³.

We also noted the number of coronary arteries with significant stenosis. A level of more than 75% organic stenosis was used in the present study, as is conventional. A coronary artery characterized by the following features was identified as the culprit vessel: (1) obliterating thrombi detectable in the lumen; (2) dominant presence in myocardium affected by a fresh myocardial infarction; and (3) distinct organic stenosis and complete obliteration by intimal edema without old myocardial infarction in the region.

We compared the rates of involvement of various culprit vessels among sudden coronary death patients and AMI patients admitted to the Emergency and Critical Care Center of Kitasato University Hospital

Table 1 Causes of Sudden Death. Coronary Artery Diseases Were Detected Most Frequently (50 Cases, 37.6%), and the Diseased Cases Included 15 Patients With Acute Myocardial Infarction (11.3%)

<i>Causes of sudden death</i>	<i>n</i>
<i>Coronary artery diseases</i>	50 (37.6%)
	(AMI=15 (11.3%))
<i>Anomaly of coronary arteries</i>	3 (2.3%)
<i>Acute cardiac dysfunction (Pokkuri disease)</i>	6 (4.6%)
<i>Other cardiac diseases</i>	6 (4.6%)
<i>Dissecting aneurysm</i>	7 (5.3%)
<i>Cerebrovascular diseases</i>	7 (5.3%)
<i>Other diseases</i>	54 (40.6%)
<i>Total</i>	133

AMI, acute myocardial infarction.

from 1 January 1990 to 30 November 1995, all of whom underwent coronary angiography to determine the main region of myocardial infarction. The patients were alive at least 1 day after admission. Consequently, 128 men and 9 women were selected as control subjects out of 711 patients (mean age 51.6 years). We compared the involvement of lesions of the left anterior descending artery (LAD) between the 2 groups using the χ^2 test.

Results

Profile of 133 Cases

Table 1 summarizes the main causes of sudden death in the 133 patients. The causes were determined only by autopsy findings. Fifty deaths (37.6%) were the result of CAD. In 15 of these 50 patients, AMI was confirmed. Anomaly of coronary arteries was seen in only 3 patients (2.3%): anomaly of a single coronary artery in 1 patient and an incompletely developed left circumflex artery in the other 2. One of last 2 patients also suffered from Wolff-Parkinson-White syndrome. Acute cardiac dysfunction, namely Pokkuri disease, was diagnosed in 6 patients (4.6%). The disease was characterized by thinning of the adrenal cortex, residual thymus, and narrowing of the aorta. There were no abnormalities in the other organs, coronary arteries, or cerebral arteries. Details of the other cardiac diseases were as follows: myocarditis in 3 patients, alcoholic cardiomyopathy in 1, cor pulmonale caused by chronic occlusive lung disease (COLD) in 1, and dilated cardiomyopathy in 1. As for other vascular diseases, 7 (5.3%) cases of dissecting aneurysm and 7 (5.3%) cerebrovascular disease were also seen. Fig 1 shows the main causes of sudden death among the

Fig 1. Causes of sudden death by age. The proportion of CAD was 10.0% in the 20–29 year age group and 22.2% in the 30–39 year age group. In contrast, coronary anomalies and acute cardiac dysfunction (Pokkuri disease) were most common in these age groups.

Fig 2. Autopsy findings in cases of sudden death due to coronary disease. Acute myocardial infarction was detected in 15 (30.0%) cases. Old myocardial infarction was also found in 20 (40.0%) cases of death due to CAD. Fresh coronary thrombus and intimal edema obliterating the coronary artery were revealed in 15 cases (30.0%). AMI, acute myocardial infarction; OMI, old myocardial infarction.

different age groups. The rate of sudden death due to CAD was 10.0% in the 20–29 year age group. Among subjects in their thirties and forties, the rate almost doubled to 22.2% and 25.7%, respectively.

Among patients in their fifties and sixties, it reached 51.4%. Anomaly of coronary arteries and acute cardiac dysfunction (Pokkuri disease) constituted the principal causes of sudden cardiac death among

subjects aged less than 40 years.

Fig 2 details autopsy findings in 50 patients who died of CAD. AMI occurred suddenly in 15 patients. A previous history of myocardial infarction was identified

Fig 3. Number of diseased coronary arteries in sudden coronary death. Three-vessel disease was most frequently seen, occurring in 50.0% of cases of sudden coronary death.

in 40.0% of patients with CAD. Out of 50 patients with CAD, 7 patients (14.0%) were free from significant stenosis of more than 75%. The lower part of Fig 2 summarizes the pathologic state of the culprit coronary artery in the 15 patients with AMI. Thrombi obliterating the total lumen of the coronary artery were found in 6 patients (12.0%). Out of these, organic coronary stenosis of more than 75% was detectable in 5 patients, whereas 75% organic stenosis was found in the remaining patient. Fig 3 shows the number of coronary arteries affected by significant stenosis in the patients who experienced sudden death due to CAD. One diseased vessel was involved in 14% of case, 2 vessels in 10%, and 3 vessels in 50%. Sixty percent of patients had multivessel disease. The culprit arteries of AMI are shown in Fig 4. The LAD was most frequently responsible for AMI, being affected in 47% of infarctions. However, this frequency was not different from that occurring in patients who survived at least 1 day after AMI. When we combined sudden cardiac death patients with AMI and acute coronary occlusion (fresh coronary thrombus or intimal edema) without fresh myocardial necrosis, the results showed the same trend. Disease of the left circumflex artery and the right coronary artery each accounted for 20% of deaths. In the remaining 13% of patients, fresh

Fig 4. Arteries involved in AMI in cases of sudden coronary death. The LAD was the most frequently involved (47.0% of cases), whereas the right coronary artery and the left circumflex artery were each involved in 20.0% of cases. The frequency of involvement of the LAD was not different from that in patients with acute myocardial infarction who survived for at least 1 day after the attack. When we combined sudden cardiac death patients with patients with acute coronary occlusion without fresh myocardial necrosis, the results showed the same trend. AMI, acute myocardial infarction; ACO, acute coronary occlusion: obstructive fresh coronary thrombus and intimal edema; LAD, left anterior descending artery; LCX, left circumflex artery; RCA, right coronary artery; LMT, left main truncus; SCD, sudden cardiac death.

Table 2 Past History in the Cases who Died Suddenly as a Result of Acute Myocardial Infarction. Angina Pectoris or Old Myocardial Infarction was Seen the Most Frequently (6 Cases) (40.0%). Hypertension in 3 (20.0%) and Diabetes Mellitus in 2 (13.3%) Were Also Demonstrated

History	n
Angina pectoris and/or old myocardial infarction	6 (40.0%)
Hypertension	3 (20.0%)
Diabetes mellitus	2 (13.3%)
Cerebrovascular diseases	1 (6.7%)
No history (including patients whose history was unknown)	9 (60.0%)

Acute myocardial infarction, n=15.

Table 3 Culprit Vessels for the Previous Infarction in the 6 Patients who Died From a Re-Attack of Their Acute Myocardial Infarction. The LAD was the Most Frequent, Making up 50.0% of the Cases

Coronary lesion	n
Left anterior descending artery (LAD)	3 (50.0%)
Left circumflex artery (LCX)	0 (0.0%)
Right coronary artery	1 (16.7%)
LAD and LCX	1 (16.7%)
Three vessels	1 (16.7%)
Indeterminate	0 (0.0%)
Total	6

myocardial infarction was confirmed pathologically. However, we failed to identify the culprit vessel because no occluded coronary arteries were found and region of myocardial necrosis could not be identified. Table 2 documents the histories of patients who died suddenly from AMI. A past history of angina pectoris and/or old myocardial infarction was the most frequent recalled event (40.0%), followed by hypertension (20.0%) and diabetes mellitus (13.3%). Forty percent of patients with AMI exhibited symptoms of some sort before their prodromal attack. Table 3 shows the culprit vessels involved in previous infarctions in the 6 patients who died from recurrent AMI. The LAD was the culprit vessel in 83.3% of coronary lesions.

Discussion

Sudden Cardiac Death as a Result of CAD

In the literature, CAD is cited as the cause of sudden cardiac death in 24–73.5% of cases^{4–7} In Japan, in our analysis using official death certificates in Niigata Prefecture from 1984 to 1986, the rate of sudden coronary death was directly estimated as 17.0% from the analysis of death certificates⁸ In Japan, if the cause

of sudden death is unknown, it tends to be described as “acute heart failure” on death certificates. For that reason, the proportion of sudden coronary deaths among cases sudden death is thought to be relatively low.

In the present study, CAD was the cause in 37.6% of deaths, as shown in Table 1, higher than those in any previous reports from Japan^{8,9} In the previous studies, patients of all ages were included. If subjects younger than 20 year old were excluded, the rate would increase.

The incidence increases gradually with age. The frequency of CAD as a cause of cardiac death in younger subjects (less than 40 year old) was 10.0% among those in their twenties and 22.2% among those in their thirties, as shown in Fig 1. In Western countries, these figures are higher: 13–25% among those in their twenties and 42–58% among those in their thirties^{6,7} In Japan, the incidence of sudden coronary death is thought to be lower than in Western countries, especially in younger people.

In agreement with the findings of Kremers et al,¹⁰ 60.0% of patients who experienced sudden coronary death had multivessel disease (Fig 3). Out of 50 patients with CAD, only 7 patients (14.0%) were free from significant stenosis. This finding is in accord with a report by Roberts¹¹ in which macroscopic stenosis was dominant among patients whose deaths were due to CAD. Twenty out of 50 patients (40.0% as shown in Fig 2) had a previous history of AMI. This percentage is lower than the figure (55%) presented by Reichenbach et al¹² This gap may be due to a difference in the ages of subjects. As previously mentioned, our study was directed to patients in the prime of their life (20–60 years). Elderly persons were excluded from this study.

Sudden Cardiac Death as a Result of AMI

Among the patients whose death was caused by CAD, AMI was pathologically confirmed in 30.0%, as shown in Fig 2. Further, the presence of an AMI was not negligible in the other patients. In those patients, sudden death was frequently provoked in the acute phase of the infarction by complicated lethal arrhythmia and/or mechanical heart failure. Other autopsy reports have confirmed a rate of AMI of 12–41%,^{13–16} with an average value identical to ours, 11.3% (15 out of 133 patients). However, patients who died very soon after the onset of the disease did not always reveal clear proof of AMI. Morphological myocardial changes are thought to become apparent 6–12 h after the onset of AMI¹⁷ The pathologic limitations may underestimate the result¹⁸

Among patients who were proven by sudden death to be suffering from AMI, intraluminal thrombi totally obliterated the coronary artery in 6 cases (40.0% of patients with AMI, as shown in Fig 2). However, this rate is lower than the figure of 73.3% reported by Davis.¹⁹ A possible explanation is acceleration of thrombolysis in cadaveric blood after sudden death owing to the release of large amounts of plasminogen activators.²⁰ Of note is the fact that, in the present study, thrombi were not detected in any region where coronary stenosis was less than 75%; in every case with obstructive coronary thrombi significant coronary arteriosclerosis could be demonstrated. These results suggested that detailed interviews (mainly concerning chest symptoms in daily life) and exercise testing at health examinations are important in screening for sudden coronary death. To date, the unexpected occurrence of intraluminal thrombi in coronary arteries without significant atherosclerosis has been controversial. The number is relatively small, but the rate is considered to be 24–30% of patients with sudden death as a result of AMI.^{5,10,14,21}

Fresh myocardial necrosis that did not obliterate coronary thrombi occurred in 9 out of 15 patients (60.0%), indicating a possible link with coronary spasm.^{22,23} In such subjects, total obstruction provoked by coronary spasm might have disappeared completely in a very short time without any sequelae.

As shown in Table 2, the most frequent event identified in the past histories obtained from bereaved families and friends of patients who experienced sudden death as a result of AMI was angina pectoris and/or an old myocardial infarction. Hypertension, diabetes mellitus, and cerebrovascular diseases followed. These findings are identical to those obtained by Matoba et al.²⁴ It is well known that the relative risk of sudden cardiac death increases up to 3.3 times in the presence of previous coronary disease.²⁵ As mentioned before, most patients who died suddenly as a result of CAD suffered from multivessel disease¹⁰ and sudden death occurred after discharge from hospital in 5% of patients who were hospitalized because of AMI.⁵ These data would suggest that a group at high risk of sudden death would be those with a past history of CAD. In contrast, in some reports, 50% of sudden cardiac deaths were initial attacks of CAD.^{26,27} In the present study, 40% of the patients with AMI had preceding prodromal attacks.

The culprit artery for sudden death as a result of AMI was mostly the LAD (47.0%, as shown in Fig 4). The frequency of involvement of both the right coronary artery and the left circumflex artery was 20.0%.

It must be emphasized that a high risk of sudden death is obviously found among patients who suffer from serious stenosis in the proximal portion of the LAD. Vlay et al,²⁸ Schuster et al,²⁹ and Califf et al³⁰ have also proposed a close relationship between proximal lesions and sudden death. To protect patients with myocardial infarction and angina pectoris from sudden death, intervention in the LAD is most important. However, the rate of involvement of lesions of the LAD was not different from that in patients with AMI who were alive at least 1 day after the attack. To date, we have failed to predict individual persons who are at extremely high risk.

Anomaly of Coronary Arteries

In the present study, 3 cases of anomalous coronary arteries were found. In 1 case, the anomaly was complicated by Wolff-Parkinson-White syndrome. In these 3 cases, in addition the abnormal coronary circulation, the occurrence of serious arrhythmia including ventricular tachycardia and fibrillation was not negligible.³¹ A single coronary artery³² was found in 1 patient, but we could not find evidence of occlusive thrombus of the single coronary artery or myocardial infarction in this patient. All 3 patients were aged less than 40 - a pattern that has already been recognized.^{33,34} In those reports, abnormal origin of the coronary artery was also present,³⁵ but only the malformation has been noted here.

Limitation of the Present Study

The present study was performed on the basis of autopsy findings. Accordingly, we have not helped to elucidate the mechanism of sudden cardiac death due to functional disorders such as lethal arrhythmias or coronary spasm. How to examine the pathology of patients with functional sudden death will be a challenging task. Similarly, this study has identified another problem: how to diagnose AMI pathologically in the acute phase, especially if coronary thrombi have resolved in a very short time. In such cases, myocardial necrosis may not be detectable. It is to be hoped that new techniques will be discovered to differentiate myocardial infarction from coronary vasospasm.

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