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Sudden Death from Ischemic Heart Disease While Driving: Cardiac Pathology, Clinical Characteristics, and Countermeasures

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Background: Sudden death from ischemic heart disease while driving is an important cause of traffic accidents. This study discusses causes of traffic accidents in relation to risk factors for acute myocardial infarction such as hypertension and overwork and provides references for the early prevention and regulation of drivers' health conditions.

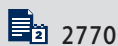
Material/Methods: Data on 21 cases of sudden death by ischemic heart disease while driving from January 2015 to December 2019 were collected. Age, symptoms, and cardiac pathological changes of patients were summarized by systematic anatomical and medical history data.

Results: Patients were 21 men with an average age of 47 ± 7.27 years (most aged 40 to 60 years), and the average weight of their hearts was 439.45 ± 76.3 g. Twelve patients had a history of hypertension, 8 had previous myocardial infarction, and 4 had fatty liver. All had at least 1 severe narrowing of a major coronary artery. Twelve patients died within a short period; 9 died more than 12 h after myocardial infarction onset. Ten patients had worked more than 80 h of overtime per month, 4 patients, more than 45 h, and 7 patients, less than 45 h.

Conclusions: Regular physical examination and information about ischemic heart disease should be emphasized for men aged 40 to 60 years who drive frequently, especially for those with hypertension, overwork, or previous myocardial infarction. Incorporating objective evaluation criteria for the severity of ischemic heart disease and overwork into health condition-related driving regulations is needed.

MeSH Keywords: **Accidents, Traffic • Coronary Disease • Death, Sudden, Cardiac • Government Regulation • Workload**

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Background

An attack of illness while driving is one of the more common causes of traffic accidents, and while the driver may die suddenly due to the onset of illness, incapacitated driving can destroy public facilities and cause serious harm to passers-by [1,2]. Many countries have various restrictions on the health conditions of drivers. In 2001, China promulgated the Physical Qualifications for Automobile Drivers and Test Protocol (GB 18463-2001), which restricts driving for people with conditions including disabilities, amblyopia, mental illnesses, epilepsy, high blood pressure, and drug abuse when obtaining a driver's license, but there are no specific requirements for physical conditions which occur after the obtainment of a driver's license [3]. In Japan, people over 75 years of age are required to pass an annual physical examination before driving, but there is still a lack of provision for the assessment and restrictions related to coronary heart disease. In the United States, there are strict regulations for older drivers. For example, the state of Iowa requires medical examinations for drivers over 70 years of age every 2 years, while the state of Arizona requires medical examinations every 5 years starting when drivers are 65 years of age [4]. Australia has formulated relevant guidelines for health professionals to assess the health of drivers, providing suggestions for the Driving License Authority to assess whether a person is suitable to hold a driver's license. Among them, guidelines on ischemic heart disease and hypertension are a focus of attention. For patients with severe disease, doctors recommend limiting driving and regularly reviewing their health conditions [5]. Different countries have different requirements for the health conditions of drivers, and there is no unified objective assessment standard for the severity of ischemic heart disease; moreover, overwork is not considered to be a factor in the assessment.

Sudden death while driving is one of the most important causes of traffic accidents, and one of the most common causes of sudden death is ischemic heart disease [1,2]. During an acute attack of ischemic heart disease, some people die within a short period of time and there is no time for treatment. Another group of people do not pay attention to an attack because they have no early symptoms or have mild symptoms [1,2,6], which is classified as silent myocardial infarction [7]. Myocardial infarction has already occurred in patients with silent myocardial infarction, and, in theory, when timely diagnosis and treatment occurs, they can avoid adverse consequences. Myocardial ischemia is usually caused by decreased blood flow or blockage in the coronary arteries. Approximately 40% of patients have transient myocardial ischemia, of whom approximately 70% to 80% present with silent myocardial infarction [8]. Patients with silent myocardial infarction usually have no subjective symptoms of ischemia or mild symptoms, but there are objective manifestations of induced myocardial ischemia in exercise or drug

stress tests, or objective evidence of coronary artery stenosis [7]. Silent myocardial infarction accounts for approximately half of all myocardial infarctions [9,10], and its risk factors include hypertension, diabetes, advanced age, emotional agitation, and fatigue [11–13]. Notably, some patients with silent myocardial infarction cannot be identified by routine electrocardiography and myocardial enzyme spectroscopy [14]. Neither patients with this type of short-term death after the onset of ischemic heart disease nor those with this type of silent myocardial infarction seek medical help in time. For the type of short-term death after the onset of ischemic heart disease described above, regular physical examinations and the establishment of preventive measures are particularly important [5], while for silent myocardial infarction patients, early identification is critical.

This study aimed to examine the forensic pathological anatomical features of sudden death from ischemic heart disease while driving and to discuss the pathologic characteristics and clinical characteristics of heart disease to provide a reference for the early prevention and regulation of drivers' health conditions.

Material and Methods

This study collected a total of 21 cases of forensic pathological anatomic reports of sudden death from ischemic heart disease while driving from January 2015 to December 2019 at the Forensic Expertise Center of the Southern Medical University. These 21 men were from inland China and were all Chinese. In all cases, the cause of death was determined by systematic and standardized pathological anatomic examination, including toxicological and alcohol screening, combined with medical history investigation, field investigation, and toxicological analysis. Forensic medical reports were confirmed and signed by more than 2 forensic medical experts. The cause of death was based on the International Classification of Diseases (ICD-10). According to the systematic anatomic examination, the injuries of the 21 drivers were all slight; in particular, there were complete pericardia and no injuries on the surface of the chest and abdomen, bleeding under the skin of the chest and abdomen, fractures of the chest and ribs, or contusion of the heart. The examination of the heart anatomy was divided into the following aspects: First, the general situation of the heart and the weight of the heart were described, and then we evaluated whether the heart was hypertrophic based on the normal reference heart weight of the Chinese population (284 ± 50 g for men, 258 ± 49 g for women) [15]. Second, the examination of the coronary arteries mainly included the assessment of atherosclerosis and stenosis of 3 blood vessels: the left anterior descending coronary artery, left circumflex coronary artery, and right coronary artery. The 3 blood vessels were cut from the beginning at intervals of 2 mm to assess

the degree of stenosis of the lumen. The degree of coronary artery stenosis was graded as I $\leq 25\%$, II was 25% to 50%, III was 50% to 75%, and IV $\geq 75\%$ [16]. Third, through the general and histopathological examination of the heart, the existence of a flaky fibrous scar was used to determine whether there had been previous myocardial infarction. The diagnosis of hypertension and fatty liver was based mainly on medical history investigation and confirmed by systematic anatomic and histopathological examination. The pathological changes in hypertension included mainly cardiac hypertrophy and atherosclerosis of small arteries in the spleen, kidney, brain, and other organs. The pathological changes in fatty liver were bullae or mixed hepatocyte steatosis mainly with bullae and vesicles, and the area of hepatocyte steatosis was greater than 5% in any visual field under 5 objective lenses [17]. The onset time of acute myocardial infarction was assessed by the following histopathological features: 1) Death occurred only a few hours after the attack, and the main pathological changes were myocardial coagulation necrosis, eosinophilic degeneration or contractile zone necrosis without obvious inflammatory cell infiltration; 2) myocardial tissue necrosis with flaky neutrophil infiltration indicated an attack of ischemic heart disease more than 12 h old; and 3) myocardial tissue necrosis with flaky neutrophil infiltration and hemosiderin particles indicated an attack of ischemic heart disease more than several days old [15,18]. The correlation between the number of working hours and disease onset was evaluated based

Table 1. Degree of coronary artery stenosis.

Coronary artery stenosis (%)	Number of cases (%)
LAD ($\geq 75\%$)	19 (90.48)
LCA ($\geq 75\%$)	7 (33.33)
RCA ($\geq 75\%$)	13 (61.90)
LAD, LCA and RCA ($\geq 75\%$)	4 (19.05)

on Japan's karoshi regulations for cerebrovascular and cardiovascular disease (excluding injuries) standards [19,20] as follows: 1) In the 6 months before the onset of the disease, the overtime per month reached 45 h, suggesting a correlation between overwork and coronary heart disease attack; 2) overtime exceeded 45 h per month, and the longer the overtime was, the stronger the correlation; and 3) 1 month before the onset of the disease, overtime was more than 100 hours, or 2 to 6 months before the onset, overtime was more than 80 h per month; both conditions were considered to have a strong correlation between overwork and coronary heart disease attack. Work-related information mainly came from family members and the certification of the employer. This study was approved by the Institutional Review Committee of the Forensic Expertise Center of Southern Medical University, and autopsy of the deceased was performed with informed consent of family members.

Table 2. Comparison of type I and type II of sudden death from ischemic heart disease (type I was identified as myocardial infarction for less than 12 h, type II was identified as myocardial infarction more than 12 h old).

The onset time of ischemic heart disease	Age	Cardiac hypertrophy	History of hypertension	Previous myocardial infarction	Fatty liver	Overtime more than 45 h per month in the 6 months before the onset of ischemic heart disease
Type I (12, 57.14%)	45.22 \pm 7.69	11 (91.67%)	6 (50%)	4 (33.33%)	3 (25%)	7 (58.33%)
Type II (9, 42.86%)	51 \pm 4.76	8 (88.89%)	6 (66.67%)	4 (44.44%)	1 (11.11%)	7 (77.78%)
Total	47 \pm 7.27	19 (90.48%)	12 (57.14%)	8 (38.10%)	4 (19.05%)	14 (66.67%)

Table 3. The correlation between overwork and ischemic heart disease (type II was identified as myocardial infarction more than 12 h old).

Overtime per month in the 6 months before the onset of ischemic heart disease	Age	Cardiac hypertrophy	History of hypertension	Previous myocardial infarction	Type II
>80 h (10, 47.62%)	50.67 \pm 4.74	9 (90.0%)	7 (70.0%)	3 (30.0%)	5 (50.0%)
45–80 h (4, 19.05%)	38.5 \pm 7.78	3 (75.0%)	1 (25.0%)	1 (25.0%)	2 (50.0%)
<45 h (7, 33.33%)	39 \pm 0	7 (100.0%)	4 (57.14%)	4 (57.14%)	2 (28.57%)
Total	47 \pm 7.27	19 (90.48%)	12 (57.14%)	8 (38.10%)	9 (42.86%)

Results

Twenty-one men with an average age of 47 ± 7.27 years and an average heart weight of 439.45 ± 76.3 g were included in the study. All patients had at least 1 severe narrowing of a major coronary artery, usually the left anterior descending coronary artery (**Table 1**). There were 19 patients with cardiac hypertrophy, 12 patients with a history of hypertension, 8 patients with a history of previous myocardial infarction, and 4 patients with a fatty liver, and 9 patients were late presenters after myocardial infarction (type II) (**Table 2**). There were 10 cases of patients working more than 80 h of overtime per month, 4 cases working more than 45 h of overtime per month, and 7 cases with less than 45 h of overtime per month (**Table 3**).

Discussion

Sudden illness while driving is one of the important causes of traffic accidents, among which ischemic heart disease is one of the most common causes [1,2,6]. When a driver has a sudden heart attack while driving, normal driving is incapacitated, which can cause not only the sudden death of the driver but also fatal injury to passersby and loss of public property. These losses cause tremendous harm to families and society. Some scholars have used autopsy data to explore the probability of traffic accidents in patients with coronary heart disease [21], but the risk factors related to acute myocardial infarction, such as hypertension and overwork, were not discussed.

In the present study, only 2 of the 21 patients with sudden death from ischemic heart disease while driving complained of symptoms of abdominal discomfort or nausea before death occurred. The remaining 19 drivers had no obvious symptoms or did not take their symptoms seriously because they were mild. The cause of death was determined by autopsy and histopathological examination after death. The age of the 21 drivers, all men, was mainly between 40 and 60 years old, and the average weight of their hearts was generally higher than normal. The left anterior descending coronary artery had the most severe atherosclerosis and stenosis among the 3 main coronary arteries. There were 12 patients (57.14%) with a history of hypertension, 8 patients (38.10%) with prior myocardial infarction, and 4 patients (19.05%) with pathological changes characteristic of fatty liver, suggesting that cardiac hypertrophy, severe coronary atherosclerosis, hypertension, previous myocardial infarction, and fatty liver may be risk factors for sudden death from ischemic heart disease [11–13]. The family members of the 8 patients who had had myocardial infarction attacks believed that there was no previous history of ischemic heart disease, indicating that the previous attack may have been silent myocardial infarction.

The 21 cases in this study can be divided into type I and type II sudden death according to the time of onset of the ischemic heart disease. Type I is death within a short period after the onset of ischemic heart disease and includes a total of 12 cases (57.14%). Type II is when the onset time of ischemic heart disease is more than 12 h before death, which includes a total of 9 patients (42.86%), including 2 patients with myocardial infarction lasting several days, and whose death was caused by silent myocardial infarction; these patients did not pay attention to their symptoms because they were asymptomatic or had mild symptoms. Although there were obvious differences in the onset time of ischemic heart disease attacks, failing to seek medical attention in time is a common feature, and severe coronary atherosclerosis, cardiac hypertrophy, hypertension, and a history of myocardial infarction may be common risk factors [11–13]. Indeed, patients with type II sudden death from ischemic heart disease have already experienced an ischemic heart disease attack. In theory, when timely diagnosis and treatment occurs, there is a chance to avoid the outcome of death. Moreover, a patient may not be completely asymptomatic after the onset of myocardial infarction. In fact, 2 of the 9 patients with type II sudden death from ischemic heart disease complained to their family members of abdominal discomfort or nausea. Patients with type II may not be sensitive to early myocardial infarction, which is related to a decreased sensitivity to pain. According to research, patients with silent myocardial infarction have a higher pain tolerance than for those experiencing a typical myocardial infarction [22], and pain sensitivity adjusts and affects the clinical manifestations of the disease [23]. The difference in central pain regulation has been proposed as one of the causes of painless ischemia. Activation of the thalamus can be seen in angina and asymptomatic myocardial ischemia, but activation of the frontal cortex seems to be necessary for the perception of myocardial pain [24]. For type I and type II, early diagnosis and early intervention are key [1,5]; therefore, regular physical examination and objective assessment of the severity of ischemic heart disease are important. Compared with patients with type I sudden death from ischemic heart disease, patients with type II can be easily overlooked. First, doctors must be familiar with the concept of silent myocardial infarction and, second, they must be aware that electrocardiogram and myocardial enzyme spectrum tests may not recognize some cases of silent myocardial infarction [14,25]. It is very important to recognize these patients as early as possible and increase the education of silent myocardial infarction. Further, it is recommended that even mild symptoms should be treated promptly. It is necessary to advise people with severe coronary atherosclerosis, especially those with cardiac hypertrophy, hypertension, or a history of myocardial infarction, to not drive or at least restrict their driving.

There were 14 cases of overwork in the present study, accounting for 66.67% of the 21 total cases. It has been reported that long working hours can increase blood pressure [26] and increase the risk of acute attacks of cardiovascular and cerebrovascular diseases [27]. Some scholars have proposed that if a person works more than 50 h per week, the probability of having diseases such as hypertension and obesity is significantly higher than that of people who work standard hours, and if a person works more than 60 h per week, the probability of sudden death due to an acute attack of cardiovascular and cerebrovascular diseases is 2 times that of those who work standard hours [28,29]. Xiao Ning et al. proposed that overwork itself can have adverse effects on the cardiovascular system and can even cause sudden death due to arrhythmia [20]. With the economic development in China, the pressure of competition in all areas of life is great, the overtime culture prevails, and sudden deaths due to long working hours have been reported occasionally [30]. Among the 21 patients in this study, 10 patients (47.62%) worked more than 80 h of overtime per month, which is consistent with the strong correlation found between overwork and the onset of disease [19,20], and 4 patients (19.05%) worked between 45 and 80 h of overtime per month, which is also consistent with the correlation found between overwork and the onset of disease [19,20]. In 14 patients involved in overwork, at least 1 of the 3 main coronary arteries had severe atherosclerosis and stenosis, and there were 12 patients (85.71%) with hypertrophy, 8 patients (57.14%) with a history of hypertension, 4 patients (28.57%) with a history of myocardial infarction, and 7 patients (50%) with myocardial infarction longer than 12 h from onset. This study suggests that overwork can be an important risk factor for acute myocardial infarction attacks while driving. Therefore, it is important for patients with risk factors such as severe coronary atherosclerosis, cardiac hypertrophy,

hypertension, and history of myocardial infarction, especially those who also have overwork, to be paid considerable attention. Just as the American Heart Association takes corresponding management measures after assessing the level of syncope patients [31], objective evaluation standards for the severity of ischemic heart disease and overwork should be established to provide a basis for the formulation of relevant laws and regulations.

Conclusions

We suggest that the influence of ischemic heart disease and overwork on driving should be considered for men aged 40 to 60 years who drive often, especially when there are risk factors for acute myocardial infarction attack and overwork. In these cases, we suggest that driving should be limited. It is necessary to establish objective evaluation criteria for the severity of ischemic heart disease and overwork and incorporate it into health condition-related driving regulations.

This study collected only 21 cases of sudden death from ischemic heart disease while driving. Whether there is a difference between type I and type II sudden death from ischemic heart disease and the correlation with overwork is still unclear. It is necessary to expand the sample size in further research to objectively evaluate the severity of ischemic heart disease and overwork and provide a basis for the formulation of relevant laws and regulations.

Conflict of interest

None.

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