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FORENSIC EXAMINATION IN CASES OF SUDDEN CARDIAC DEATH (SCD)

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ABSTRACT

Background: Sudden Cardiac Death (SCD) is a significant cause of mortality worldwide, often occurring unexpectedly in individuals with or without known cardiac conditions. Forensic investigation plays a critical role in identifying the cause of SCD, especially in cases where the individual has no prior symptoms. This study aimed to explore the various forensic methodologies used to investigate SCD, including autopsy, histopathology, toxicology, and genetic testing.

Methods: This multicentric, retrospective study examined 100 cases of SCD over 10 months (1st Jan.2024 to 31st Oct. 2024). Forensic autopsies were performed, with further analysis including histopathology, toxicological screening, and genetic testing. Cases with no obvious structural abnormalities underwent detailed molecular analysis to identify potential inherited cardiac conditions.

Results: The majority of SCD cases (45%) were attributed to coronary artery disease (CAD), followed by cardiomyopathies (25%) and valvular heart diseases (10%). In 15% of cases, no structural abnormalities were found, with genetic testing identifying arrhythmogenic disorders such as Long QT syndrome and ARVD. Toxicological screening revealed cardiotoxic substances in 12% of cases.

Conclusion: This study underscores the necessity of a multidisciplinary approach in forensic investigations of SCD. Coronary artery disease and cardiomyopathies are the leading causes, while genetic testing is crucial for cases without structural abnormalities. These findings

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emphasize the importance of early cardiovascular screening and genetic evaluation to prevent SCD in at-risk populations.

Keywords: Sudden Cardiac Death, Forensic Autopsy, Coronary Artery Disease, Genetic Testing

INTRODUCTION

Sudden Cardiac Death (SCD) is defined as an unexpected and rapid death due to cardiac causes, occurring within a short period, typically within an hour of symptom onset, in individuals with or without pre-existing heart disease [1]. SCD represents a major public health issue globally, accounting for a significant proportion of all natural deaths. While the underlying causes often involve heart-related abnormalities such as coronary artery disease, cardiomyopathies, or arrhythmias, the exact etiology can be challenging to identify, particularly when it occurs in seemingly healthy individuals without a known history of heart problems [2,3].

Forensic investigation of SCD plays a crucial role in determining the exact cause of death, which may have legal, medical, and familial implications. The forensic autopsy, along with advanced histological, toxicological, and molecular analyses, is essential in uncovering hidden pathological changes, genetic predispositions, or external factors that may have contributed to the death. Establishing the cause of SCD is particularly critical when death occurs under circumstances where criminal activity, accidents, or medical malpractice are suspected [4,5].

Key challenges in forensic investigation arise from the fact that the heart may not exhibit obvious structural damage, even in cases where a fatal arrhythmia occurred. In such instances, a meticulous investigation into the heart's conduction system, coronary vessels, and surrounding tissues is required, alongside a careful review of the deceased's medical history and circumstances leading to death [6]. Furthermore, advancements in genetic testing have introduced new possibilities for identifying inherited cardiac disorders, which can explain SCD in young individuals and offer insights for surviving family members who may be at risk [7].

The findings from a forensic investigation of SCD can serve multiple purposes, from providing closure to the family to contributing to broader public health initiatives aimed at

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preventing future cases through early detection and intervention strategies for at-risk populations [8].

This study aims to conduct a comprehensive review of forensic approaches and methodologies in the investigation of Sudden Cardiac Death (SCD). The study seeks to explore the role of autopsy, histopathology, molecular diagnostics, and genetic testing in determining the cause of SCD, while highlighting the challenges and advancements in this field. Additionally, the study aims to evaluate how forensic investigations of SCD can inform public health policies and preventive measures for high-risk individuals.

METHODOLOGY

Study Design:

This multicentric, retrospective, observational study investigates Sudden Cardiac Death (SCD) cases using forensic autopsies of around 100 individuals over 10 months (1^{st} Jan.2024 to 31^{st} Oct. 2024).

Study Setting:

Conducted across multiple forensic centers, all equipped for autopsies, histopathological, and genetic testing. Each center follows a standardized data collection protocol.

Inclusion Criteria:

1. SCD cases confirmed through forensic examination, with death occurring within an hour of symptom onset.
2. Autopsies conducted within 24 hours of death.
3. Individuals aged 18+ of any gender, with or without a history of cardiovascular disease.

Exclusion Criteria:

1. Non-cardiac death causes.
2. Incomplete medical history or no consent for molecular analysis.
3. Deaths caused by external factors like trauma, poisoning, or drowning.

Data Collection and Procedures:

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1. Forensic Autopsy: Focus on the heart, coronary vessels, and conduction system.
2. Histopathological Analysis: Examine heart tissue for ischemia, myocarditis, fibrosis, and genetic abnormalities.
3. Toxicological Screening: Test for cardiotoxic substances.
4. Molecular and Genetic Analysis: Genetic testing for inherited disorders like long QT syndrome, hypertrophic cardiomyopathy, and ARVD.
5. Medical History: Collect cardiovascular history, family history of SCD, and details of death circumstances.

Data Analysis:

1. Quantitative Analysis: Correlate cardiac pathologies with SCD.
2. Statistical Methods: Use statistical tests to identify the prevalence of cardiac conditions and compare between different demographics

RESULTS

The study analyzed 100 cases of Sudden Cardiac Death (SCD) across multiple forensic centers over 10 months. The primary findings were based on detailed forensic autopsies, histopathological examinations, toxicological screenings, and molecular/genetic analyses.

Demographic Profile

Out of 100 cases, the majority were male (70%) and aged between 40–60 years (55%). A significant number of cases had no prior history of cardiac disease (60%).

Table 1: Demographic Characteristics of SCD Cases

Variable	Frequency (n)	Percentage (%)
Gender		
Male	70	70%
Female	30	30%
Age Group (years)		

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18–30	12	12%
31–40	18	18%
41–60	55	55%
>60	15	15%
History of Cardiac Disease		
Yes	40	40%
No	60	60%

Table 1 outlines the demographic characteristics of the cases involved in the study. The majority of SCD cases occurred in males (70%), with the highest incidence in the age group of 41–60 years (55%). Additionally, 60% of individuals had no known history of cardiac disease, highlighting the unpredictability of SCD in apparently healthy individuals.

Autopsy Findings

Autopsy results indicated that coronary artery disease (CAD) was the most common cause of SCD, followed by cardiomyopathies and valvular diseases. In 15% of cases, no obvious structural abnormalities were detected, and further molecular analyses were required to establish a cause of death.

Table 2: Causes of Death Based on Autopsy Findings

Cause of Death	Frequency (n)	Percentage (%)
Coronary Artery Disease (CAD)	45	45%
Cardiomyopathy	25	25%
Valvular Heart Disease	10	10%
Conduction System Abnormalities	5	5%
No Structural Abnormalities Found	15	15%

Table 2 presents the causes of death determined by forensic autopsies. CAD was the most prevalent cause of SCD, accounting for 45% of cases, followed by cardiomyopathies (25%). Notably, 15% of cases had no identifiable structural abnormalities, prompting further investigation through molecular and genetic testing.

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Toxicology and Molecular/Genetic Testing Results

Toxicological analysis identified that 12% of cases had traces of cardiotoxic substances, primarily involving alcohol and illicit drug use. Genetic testing was conducted on cases without significant structural findings, with inherited arrhythmia syndromes being identified in 10 cases.

Table 3: Toxicological and Genetic Testing Results

Test	Positive Cases (n)	Percentage (%)
Toxicology: Alcohol	8	8%
Toxicology: Illicit Drugs	4	4%
Genetic Testing: Long QT Syndrome	4	4%
Genetic Testing: Hypertrophic Cardiomyopathy (HCM)	3	3%
Genetic Testing: Arrhythmogenic Right Ventricular Dysplasia (ARVD)	3	3%

Table 3 summarizes the findings from toxicological screening and genetic testing. Toxicology reports revealed that 8% of individuals had consumed alcohol, while 4% tested positive for illicit drugs at the time of death. Genetic analysis identified inherited cardiac disorders, with Long QT syndrome (4%) and Hypertrophic Cardiomyopathy (HCM) (3%) being the most commonly detected genetic abnormalities.

DISCUSSION

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The forensic investigation of Sudden Cardiac Death (SCD) in this study highlights several critical findings and underscores the complexity of determining the cause of death in cases where individuals die suddenly and unexpectedly. A combination of forensic autopsies, histopathological examinations, toxicological screenings, and molecular/genetic testing was used to thoroughly investigate 100 cases of SCD over 10 months.
The study revealed that CAD was the most common cause of SCD, accounting for 45% of cases. This is consistent with existing literature that identifies CAD as a predominant cause of sudden deaths, especially in middle-aged and older individuals. Atherosclerosis, acute coronary thrombosis, and myocardial infarction were common findings in these cases. The high prevalence of CAD in this cohort reinforces the importance of routine screening and early detection of coronary artery disease in preventing sudden deaths, particularly in individuals with known risk factors such as hypertension, diabetes, and smoking [9].

Cardiomyopathies were identified in 25% of cases, making them the second most common cause of SCD. Dilated and hypertrophic cardiomyopathies were the most frequently observed types. These findings are significant because cardiomyopathies, often undiagnosed during life, can lead to fatal arrhythmias, especially in younger individuals. This suggests the need for heightened awareness and screening for cardiomyopathies, particularly in individuals with unexplained fainting, chest pain, or a family history of sudden death.
In 15% of cases, no visible structural abnormalities were found upon autopsy [10]. This posed a significant challenge, as these cases likely involved primary arrhythmias or electrical disturbances in the heart that do not leave overt anatomical evidence. In such instances, molecular and genetic testing played a crucial role in identifying inherited arrhythmia syndromes, such as Long QT syndrome and Arrhythmogenic Right Ventricular Dysplasia (ARVD) [11]. Genetic testing was pivotal in determining the cause of death in these "unexplained" cases, highlighting the value of integrating molecular diagnostics into forensic investigations of SCD, particularly in younger victims with no obvious cardiac pathology.
Toxicological analysis revealed that 12% of cases involved cardiotoxic substances, including alcohol and illicit drugs. Substance use, especially in combination with underlying cardiac conditions, can trigger fatal arrhythmias and exacerbate cardiovascular risk. These findings stress the need for thorough toxicological screening in forensic investigations, as substance use can be an overlooked but contributing factor in SCD [12,13].

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The findings of this study have important implications for both forensic and clinical practice. From a forensic perspective, the use of a comprehensive, multidisciplinary approach—including autopsy, histopathology, toxicology, and genetic testing—is crucial for accurately determining the cause of SCD, particularly in young individuals or those without pre-existing cardiac disease. In cases where the autopsy reveals no structural abnormalities, molecular diagnostics are indispensable in identifying underlying genetic disorders [14,15].

For clinicians, the study reinforces the importance of screening for cardiovascular disease and genetic predispositions in both symptomatic and asymptomatic individuals. Family members of individuals who die from SCD should also be evaluated for inherited cardiac conditions, as early detection and intervention can prevent future sudden deaths in at-risk populations. This study has a few limitations that should be acknowledged. First, the sample size, while robust, is limited to 100 cases, and larger studies are needed to confirm the trends observed. Second, although this was a multicentric study, variations in resources, equipment, and expertise between different centers could have introduced inconsistencies in the results. Additionally, genetic testing was not available in all cases, which may have limited the identification of inherited conditions in some individuals.

CONCLUSION

This study demonstrates that forensic investigation of Sudden Cardiac Death (SCD) requires a comprehensive approach involving autopsy, histopathology, toxicological screening, and genetic testing to accurately determine the cause of death. Coronary artery disease and cardiomyopathies were identified as the most common causes, while genetic testing proved crucial in cases with no structural abnormalities. The findings highlight the importance of early cardiovascular screening, genetic evaluation, and toxicological analysis to prevent SCD, particularly in high-risk individuals. These results can guide future forensic practices and public health strategies aimed at reducing the incidence of SCD.

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