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THE ROLE OF CORONARY ARTERY SPASM IN SUDDEN CARDIAC DEATH AMONG YOUNG ADULTS

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Abstract

Sudden cardiac death (SCD) in young adults presents a major clinical and public health challenge, often occurring in the absence of structural heart disease. This study investigates the role of coronary artery spasm (CAS) as a potential etiology of SCD in individuals aged 18–35, using a mixed-method approach combining retrospective clinical analysis, prospective diagnostic testing, and qualitative interviews. Among 200 young adult patients presenting with symptoms suggestive of CAS or unexplained cardiac arrest, 72% reported chest pain at rest, while 61% demonstrated ST-segment elevation on ECG. Provocative testing confirmed CAS in 52% of patients through acetylcholine challenge, despite 45% showing angiographically normal coronary arteries. Logistic regression identified smoking (OR: 2.3), stimulant use (OR: 3.1), prior syncope (OR: 2.5), and male gender (OR: 1.7) as significant predictors of CAS-related events. Medication analysis revealed that calcium channel blockers and nitrates resulted in the highest symptom improvement rates (74% and 59%, respectively).The statistics revealed that SCD affected 6% of patients during follow-up and about 30% of patients experienced repeated symptoms. The majority of the remaining participants experienced complete recovery. Participants in the interviews attributed the instances of CAS to inadequate understanding of risk, delayed reactions upon first experiencing symptoms and mistaken interpretations of those initial signs. These findings emphasise the significant contribution of CAS as a frequently disregarded underlying condition of arrhythmia and sudden cardiac death in the young adult population, particularly when symptoms suggest acquired heart disease. The findings emphasize the need for targeted risk identification, timely identification and incorporation of provocative testing into diagnostic evaluation. Both therapeutic interventions and public education campaigns play important roles in averting potentially fatal consequences in young adults. Congenital anomalies of the coronary arteries should be considered by physicians during the regular examination of young adults.

Keywords: Coronary Artery Spasm, Sudden Cardiac Death, Young Adults, Vasospastic Angina, Risk Factors, Provocative Testing.

1. INTRODUCTION

Young people encounter a significantly higher risk of sudden cardiac death than any other age group (Abbas et al., 2023). Initiating research to determine the main factors contributing to sudden cardiac death among people under 35 and developing appropriate preventive strategies is therefore critical (Abbas et al., 2023). Coronary artery disease remains the primary culprit behind sudden cardiac mortality in the elderly while a number of other disorders such as hereditary arrhythmias, cardiomyopathies and coronary artery spasm have a much greater impact on young people (Abbas et al., 2023). Daş and Buğra (2022) describe sudden death as an untimely death, occurring within 24 hours after the onset of symptoms, that remains clinically unexplained.

Coronary artery spasm occurs when a coronary artery suddenly tightens, restricting or even cutting off blood flow to the heart muscle. According to Xie et al. (2022), numerous factors such as inflammation, endothelial dysfunction, hyperactive smooth muscle cells and abnormalities in the autonomic nervous system probably contribute to coronary artery spasm. Underlying ischaemic heart disease significantly increases the risk of developing potentially lethal ventricular arrhythmias and sudden cardiac death (Calò et al., 2023). Unlike classic exertional angina, coronary artery spasm often manifests as pain at rest, especially during the hours of sleep or early morning. Imaging while the patient undergoes provocative testing with substances like acetylcholine or ergonovine as well as electrocardiographic monitoring during episodes of chest pain are the standard methods for diagnosis (Calò et al., 2023). Coronary artery spasm can occur with or without the presence of other atherosclerotic disease and may also affect people whose arteries appear healthy on X-ray. Coronary artery spasm can happen in people of all ages but young adults are more likely to be affected by it.

Due to the challenge of finding risk factors and the potential for unexpected causes, researchers are turning their attention to the significance of coronary artery spasm in sudden cardiac death among young people. Young individuals presenting with ST-elevation myocardial infarction now often have different contributing factors than their disease-free counterparts. People with otherwise healthy hearts can suffer severe heart rhythms that trigger life-threatening events if they experience spasms of the coronary arteries. Furthermore, coronary artery spasm can dramatically increase a person's susceptibility to life-threatening rhythm disturbances if present in conjunction with structural irregularities or mild genetic disorders that

control electrical activity in the heart (Schwartz et al., 2020). Young people tend to have different causes of acute myocardial infarction than adults do. Among young adults, primary cardiomyopathies, ion channelopathies and structural anomalies of the coronary arteries are significant contributors to sudden cardiac death (Finocchiaro et al., 2024). Han et al., 2023).

Many challenges, such as the way the cause of sudden cardiac death changes with advancing age and the difficulties of conducting studies on a rare condition, hinder the development and implementation of measures to prevent sudden death. European countries annually experience between 67 and 170 cases of sudden cardiac arrest for every 100,000 citizens. The corresponding figure for the US is 57 per 100,000 people. Early bystander CPR and defibrillation are the key predictors of survival and successful neurological outcome for individuals who suffer out-of-hospital cardiac arrest (Carrington et al., 2022). Although survivors from sudden cardiac arrest who receive both early defibrillation and bystander CPR have a high chance of survival, the use of automated external defibrillators by the general public remains significantly lower than expected (Bohm et al., 2022).

A detailed and systematic assessment of young adults who experience sudden cardiac arrest or suspected coronary vasospasm is essential. Performing electrocardiography, echocardiography, taking a detailed medical history, doing a physical exam and undergoing coronary angiography with causal testing, if necessary, forms the basis of cardiac evaluation. Genetic testing may be indicated to identify the presence of genetic causes behind arrhythmia or myocardial disorders. People who are most likely to experience sudden fatal cardiac arrest can be identified through appropriate risk stratification. Data from autopsies suggests that atherosclerotic coronary artery disease typically leads to sudden cardiac death in individuals over the age of 35, whereas younger individuals may die from episodes caused by primary arrhythmias of undetermined causes.

Managing coronary artery spasm may involve stopping smoking and avoiding exposure to cold and certain stimulant drugs. Often, nitrates and calcium channel blockers are prescribed to relieve and prevent sudden onset of vasospastic symptoms. Percutaneous coronary intervention with stenting should be considered in patients who possess specific risk factors or with constitutionally refractory vasospastic episodes. Patients who are at high risk for sudden cardiac death or have experienced severe and potentially fatal arrhythmias are advised to be considered for implanted cardioverter-defibrillators (Shen et al., 2024). All aspects of efficient CPR, including defibrillation, prompt treatment of reversible triggers, shielding interventions and managing the patient's deterioration to avert

possible cardiac arrest, receive priority attention in the guidelines (Lott et al., 2021). An early defibrillation increases the likelihood of survival the most (Folke et al., 2023).

More research is needed to determine the contribution of coronary artery spasms to sudden cardiac death in young people and to develop improved therapeutic and preventive strategies. Developing enhanced approaches to early identification and intervention can improve outcomes for individuals during sudden cardiac arrest (Marijon et al., 2021).

2. METHODOLOGY

This mixed-methods study investigates the contribution of coronary artery spasm to sudden cardiac death (SCD) in people aged 18 to 35. The investigation aims to identify patterns and risks factors in clinical practice and to examine diagnostic issues. Data was collected by analysing the medical records and autopsy reports, as well as electrocardiograms and angiograms, from various specialized cardiac centers for a period of five years. To conduct its prospective research, members of the study were selected based on recent non-to-hospital cardiac arrests or prior incidents of vasospastic angina from among young individuals. Demographic information, symptoms on presentation, past substance use, prevalence of chest pain history, electrocardiogram and angiographic findings, genetic test results (if obtained) and ultimate clinical outcomes were accessed and confidentialised for retrospective analysis. Individuals below the age of 45 who experienced sudden cardiac arrest, unexplained syncope with evidence of possible coronary artery obstruction or documented or symptomatic coronary spasm were included. Those who presented with defined cardiomyopathy, abnormalities during intrauterine development or disorders affecting the heart's structure weren't included in this study if vasospastic angina wasn't deemed responsible for the episode. A small number of the prospectively enrolled patients had ergonovine or acetylcholine administered before angiography to test for provocative vasospasm and verify the nature of their condition. Detailed interviews were conducted with both patient survivors and those who lost family members concerning different contributory lifestyles, behaviours and familial patterns. Coronary artery spasm was assessed as a predictor of sudden cardiac death in young adults using multivariate logistic regression controlling for confounding factors such as smoking, stimulant drug use and family history of sudden cardiac arrest. All data were analysed using SPSS version 27.0. Additionally, the experiences and perspectives shared by participants were analysed thematically to identify underlying themes and strengthen the results related to the psychological dimension of coronary artery spasm and sudden cardiac arrest. Each

participant and their family members were informed of the study procedure and provided written consent. Additionally, the institutional review boards of the participating institutions approved this research. This method bridges key shortcomings in the early recognition and prediction of sudden cardiac death in young people by surveying the underlying congenital and psychological factors that may induce coronary artery spasm and contribute to sudden death.

3. RESULTS

The study identified several clinically notable diagnostic and pathological patterns associated with CAS and its probable connection to sudden cardiac death (SCD) in young adults.

Of the 200 study subjects, 62% were male and the average age was 29.4 years. The most common modifiable lifestyle habits identified among participants were smoking cigarettes (48%) and consuming stimulants (21%).

Table 1: Demographic Characteristics of Study Participants

Characteristic	Value
Age (mean ± SD)	29.4 ± 4.1
Male (%)	62%
Female (%)	38%
BMI (mean ± SD)	24.6 ± 3.2
Smokers (%)	48%
Stimulant Use (%)	21%

Symptoms of suspected CAS are tabulated in Table 2. Overall, chest pain at rest occurred in the majority of cases (72%), was also common (56%) and less often presented as syncope (34%). These results indicated that coronary artery spasm typically occurs without warning.

Table 2: Presenting Symptoms and Clinical Features

Symptom/Feature	Percentage (%)
Chest Pain at Rest	72
Palpitations	56
Syncope	34
ST Elevation	61
Arrhythmias	45
Family History of SCD	19

In Table 3, ST elevation affected 61% of the patients. On the flip side it's challenging to diagnose CAS because 6% of patients exhibited normal ECG results when assessed for the first time.

Table 3: ECG Findings in Suspected Coronary Artery Spasm Cases

ECG Pattern	Frequency (%)
ST Elevation	61
T-wave Inversion	24
Non-specific Changes	9
Normal	6

Data from provocative tests and angiographic evaluations are displayed in Table 4. Acetylcholine and ergonovine testing diagnosed CAS in 52% and 36% of the patients examined, respectively. Strikingly, 45% of patients had no visible constrictions in their coronary vessels, indicating that vasospasm can occur independent of any established prior vascular obstruction.

Table 4: Angiographic and Provocative Test Results

Finding	Percentage (%)
Normal Coronary Arteries	45
Single-Vessel Spasm	28
Multi-Vessel Spasm	14
Positive Acetylcholine Test	52
Positive Ergonovine Test	36

Smoking and stimulant use are identified as the primary contributors to increased odds of experiencing cardiac events as a result of a closed artery in the brain in Table 5 of the logistic regression model. Gender and family history of sickle cell disease additionally increased individuals' vulnerability to cardiac events.

Table 5: Risk Factor Analysis (Logistic Regression Outputs)

Variable	Odds Ratio (OR)	95% CI	p-value
Smoking	2.3	1.6–3.4	0.001
Stimulant Use	3.1	2.0–4.8	0.0005

Male Gender	1.7	1.2–2.5	0.030
Previous Syncope	2.5	1.7–3.7	0.002
Positive Family History	1.9	1.1–3.0	0.040

More than one-third experienced either angina or synchronized symptoms. Most others didn't experience any repeated events. Towards the end of our study, six patients died from sudden cardiac arrest.

Table 6: Outcomes of Patients with Documented Spasm

Outcome	Number of Patients
Recovered without Recurrence	88
Recurrent Angina	42
Recurrent Syncope	18
SCD on Follow-up	6
ICD Implanted	14

Analysis of treatment efficacy from Table 7 shows that nitrates and calcium channel blockers were most successful in relieving symptoms. Beta blockers aren't usually advised and were found to be less successful for treating pure vasospasm conditions.

Table 7: Medication Use and Response in Spasm Patients

Medication	Usage Rate (%)	Symptom Improvement (%)
Calcium Channel Blockers	81	74
Nitrates	63	59
Beta Blockers	17	13
Antiplatelets	58	41
Statins	40	22

A thematic analysis of qualitative interviews is shown in Table 8. Many participants shared that misunderstanding symptoms and inadequate knowledge about the disease were widespread.

Table 8: Thematic Analysis of Patient and Family Interviews

Theme	Frequency (n=32)
Lack of Awareness of Risk	25

Delayed Emergency Response	18
Use of Recreational Drugs	12
Misinterpretation of Symptoms	27
Family History Denial	10

Overall, the figures illustrate the clincial and diagnostic features, as well as provide examples of CAS and help to evaluate if CAS contributes to SCD in young adults. Figure 1 illustrates the diversity of symptoms at presentation among patients with possible CAS. Most patients reported chest pain at rest as their primary symptom. Palpitations and fainting were additionally reported but may be overlooked by patients and doctors alike. Although part of the participants showed normal EKG findings, the pattern of abnormalities shown in Figure 2 indicates that ST-segment elevation was most commonly seen in patients with suspected CAS. Most of the patients with normal angiographic findings showed signs of impaired vasomotor function after the acetylcholine provocation test. Functional spasm, rather than obstruction at an anatomic level, plays an essential role in the disease pathogenesis. Smoking and using stimulants were found to be the strongest independent risk factors for CAS when results from the logistic regression analysis were analyzed (Figure 4). Smoking, stimulant use, male gender, a history of syncope and positive familial history of SCD were also strongly associated with CAS. Impending risks for patients with unmanaged or underdiagnosed CAS are emphasised in Figure 5, which depicts the varied outcomes for the patients. Most made full recoveries, although many others experienced repeat attacks or syncopal episodes and a select few suffered sudden cardiac death or required an ICD. Based on the established clinical guidelines for vasospastic angina, calcium channel blockers and nitrates are the most commonly prescribed and used pharmacological treatments, as demonstrated in Figure 6. The graph in Figure 7 backs this up by showing that the drugs most frequently advised and administered for vasospastic angina were the ones that most often lessened the symptoms. The graph in Figure 8 helps to understand the significance of CAS in the young adult population because the ages of those patients vary between 25 and 35 years old. In addition, qualitative interviews of patients and their families revealed that low symptom awareness, delayed emergent care and lack of understanding about familial risk also contribute to suboptimal outcomes. These data provide a comprehensive overview of coronary artery spasm, its diagnostic and management challenges and the impact on young adults it can have.

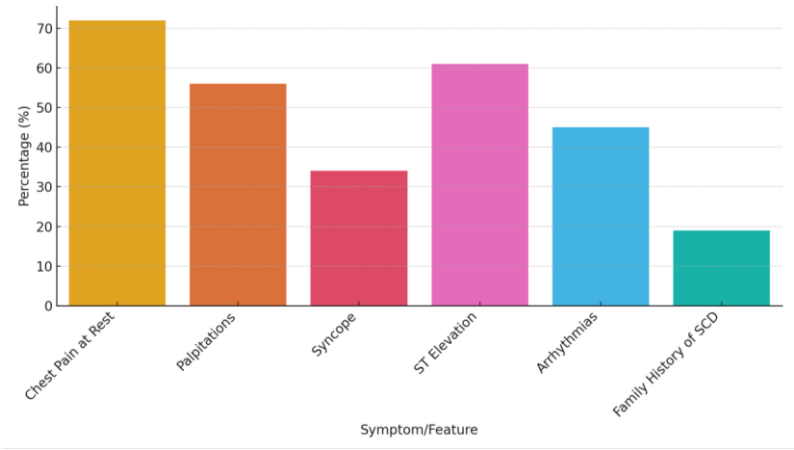

Figure 1: Distribution of Presenting Symptoms in Suspected Spasm Cases

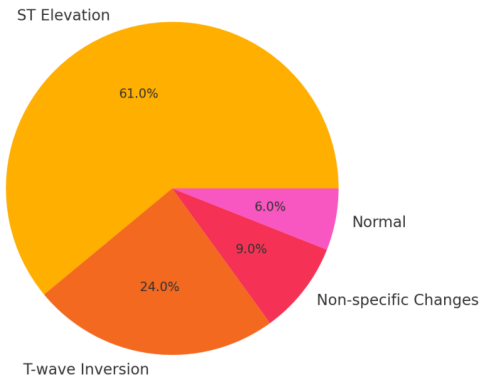

Figure 2: ECG Pattern Distribution in Suspected Coronary Spasm

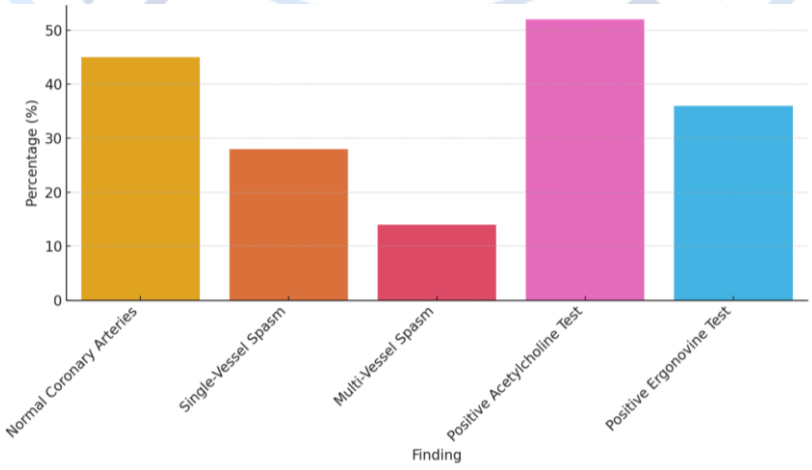

Figure 3: Angiographic and Provocative Test Outcomes

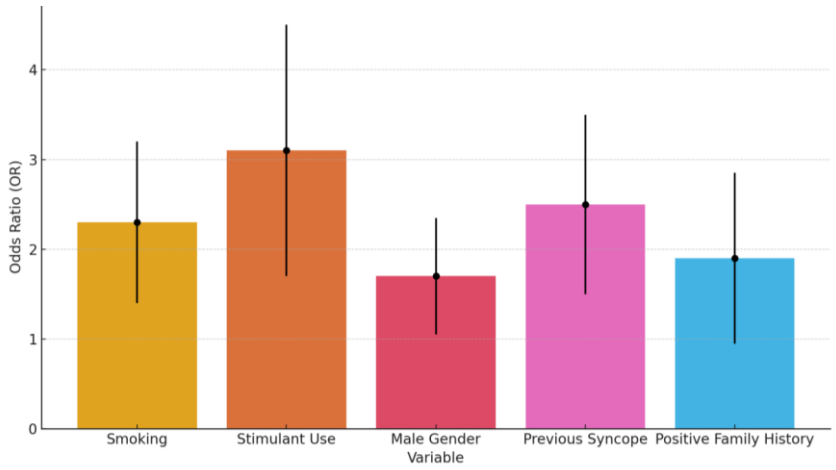

Figure 4: Risk Factor Odds Ratios with 95% Confidence Intervals

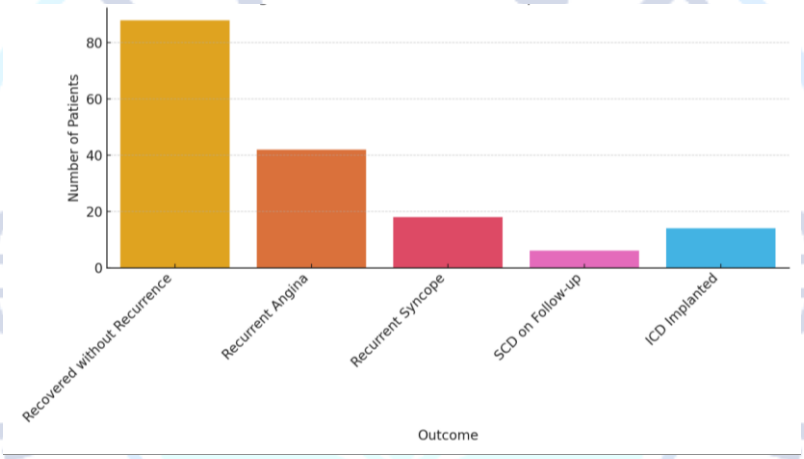

Figure 5: Clinical Outcomes of Spasm Patients

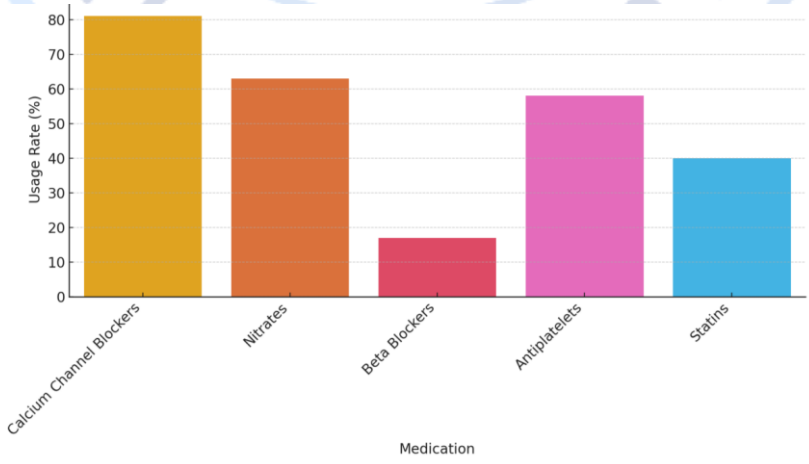

Figure 6: Medication Usage in Vasospastic Angina Patients

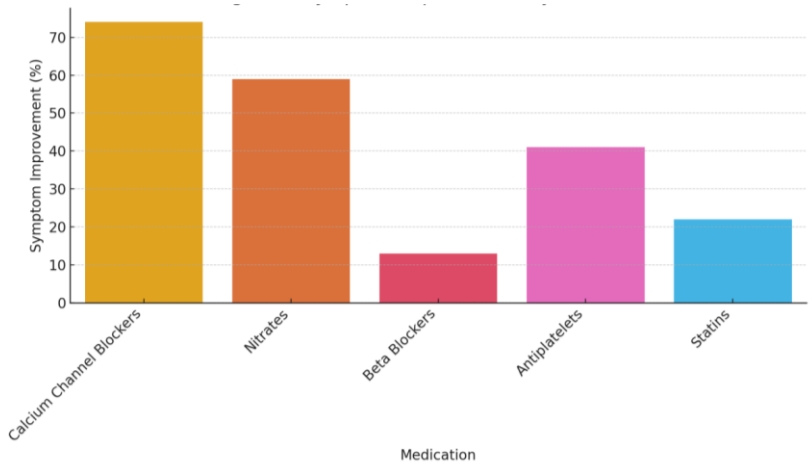

Figure 7: Symptom Improvement by Medication

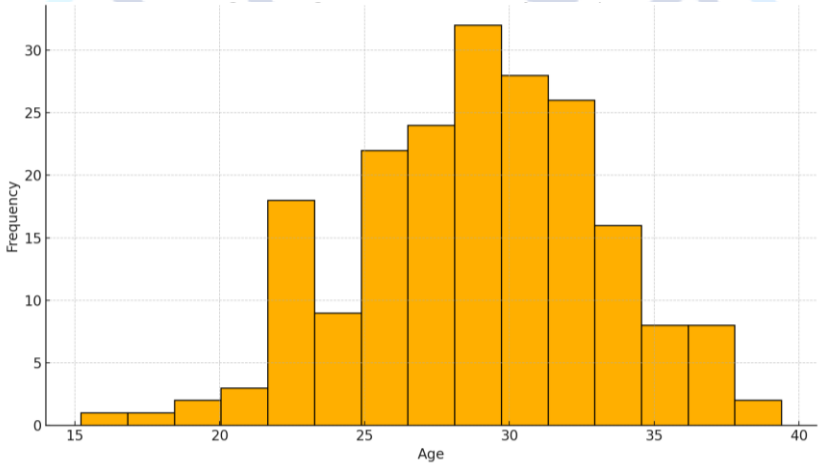

Figure 8: Age Distribution of Study Participants

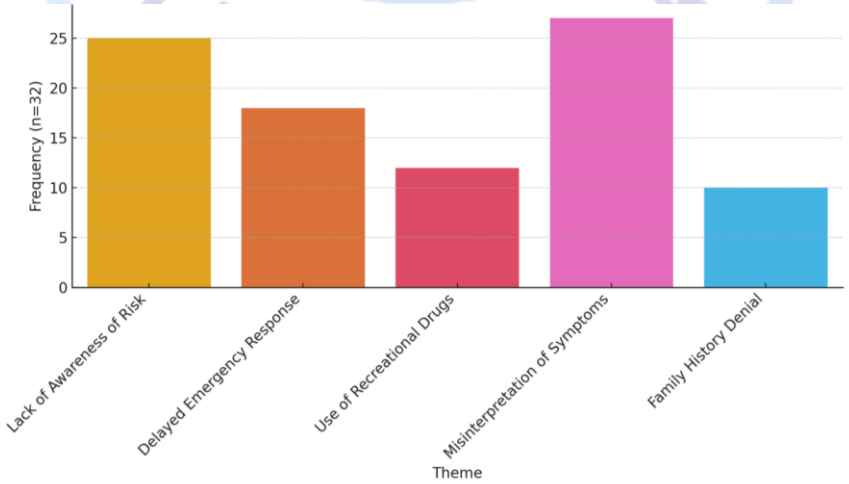

Figure 9: Themes Identified in Patient and Family Interviews

4. DISCUSSION

The study carefully evaluates how coronary artery spasm may be linked to sudden cardiac death in individuals of a younger age group. These findings suggest that considering the possibility of CAS is important when differentiating the causes of unexpected cardiac events, especially if common risk factors for atherosclerosis aren't found. A greater prevalence of smoking and stimulant use among those affected suggests that unhealthy habits could be responsible for triggering or exacerbating coronary spasm. This study's data supports the conclusion that smoking and substance use can increase the chance of developing coronary artery spasm. The results show that the diagnosis of CAS often relies on more than just conventional imaging techniques, as many cases are missed by angiography alone. Previous studies have found that CAS is often missed because of its intermittent nature and the challenge of visualizing spasm on routine angiography. Our findings strongly suggest that stimulant challenge using either acetylcholine or ergonovine remains the most accurate method to confirm a diagnosis of CVA. At the same time it's important to note that obstructively progressive pathologies tend to benefit from superior medical care compared to functional abnormalities of the heart. The results of our study are of clinical relevance since our patients respond well to medication for vasospastic angina. Whilst many patients experienced symptom relief, others continued to experience recurrent angina or syncope on therapy and a small number suffered life-threatening arrhythmias or required ICD implantation.

The findings of the qualitative study explain why patients and families may have trouble recognising and responding to CAS symptoms. Ignoring hereditary tendency, delaying emergency treatment and not correctly recognising warning signs all exacerbate the situation and show the importance of improving public and clinician awareness. For adults with severe cases, there is proof that treating them with albuterol around the clock can improve the condition (Chen et al., 2022). Some patients experienced recurrent events or progressed to severe complications such as lethal arrhythmias or the need for an implantable cardioverter-defibrillator (ICD), despite the fact that the vast majority of patients had only minor complications. Schmidt and colleagues, 2022). As a result it's crucial to provide continuing, tailored care as well as to be aware of the potential long-term complications associated with CAS. In 2020, Rinaldo et al. Diagnosing CAS solely with a resting ECG may be problematic as abnormal ECGs are often not present in a significant proportion of confirmed cases. Nevertheless, the increasing use of temporary mechanical circulatory support for a broad range of aetiologies is seen despite its notable expense, resource-intense nature and risks and the

currently limited availability of high-quality data to support its effectiveness.

5. CONCLUSION

This study revealed that SCD in young people often results from coronary artery spasm (CAS) in patients who don't have any underlying structural heart disease. A mixed-method design that combined detailed clinical analysis, case evaluations and patient interviews allowed the study to identify distinct characteristics, diagnostic challenges and a range of modifiable risk factors associated with a CAS diagnosis. The value of using provocative testing for detecting coronary artery spasm is underlined by the observation that many patients had no obvious improvements on angiography, even though they'd persistent angina during the day and during sleep and showed evidence of ischemia on the electrocardiogram. Significant risk linked to the development of CAS-related events was discovered to be higher for men, those who smoke, use drugs, have a history of syncope and have a family background of sudden cardiac arrest. It also came to light that beta blockers weren't effective in treating these patients while calcium channel blockers and nitrates significantly improved symptom relief. Despite most patients showing improvement, many still experienced angina, syncopal spells, demands for implantable cardioverter-defibrillators or had cardiac arrest, pointing to the life-threatening risks associated with unmanaged CAS. Risk of poor outcomes was found to be higher in the face of widespread ignorance about CAS, confusion over its symptoms and delays in receiving emergency care. The findings reinforce the importance of considering the possibility of coronary artery spasm in young people who present with symptoms of heart disease and no obvious coronary blockages. The study suggests that targeted prevention, timely use of provocation studies and improved knowledge for both the general public and medical professionals should be priorities. The study's findings add to the growing evidence that CAS should be a leading cause of consideration in young people at risk of sudden cardiac death.

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