Pathology of Sudden Cardiac Death in a Metropolitan Forensic Medicine Institution in Thailand

พยาธิสภาพของหัวใจในผู้เสียชีวิตจากภาวะหัวใจวายเฉียบพลันที่ได้รับการชันสูตรพลิกศพในสถาบันนิติเวชประเทศไทย

Chanyanut Wongthongmana and Sakda Sathirareuangchai*
Faculty of Medicine Siriraj Hospital, Mahidol University

ชัญญานุช วงศ์ทองมานะ และ ศักดา สถิรเรืองชัย*
คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล

Received: March 12, 2024 | Revised: April 16, 2024 | Accepted: April 25, 2024

บทความวิจัย (Research Article)

ABSTRACT

Sudden cardiac death (SCD) is a condition that is relatively common worldwide. However, the data on the characteristic of SCD is sparse in Southeast Asian countries. The authors performed a retrospective review of forensic autopsy report at Siriraj Hospital, the largest hospital on the Western Bangkok metropolitan area. Adult autopsy cases over 18 years of age from 2018 through 2020 were reviewed for demographic data (age, sex, body mass index [BMI], circumstance of death), heart weight, cardiac pathology, and cause of death. A total of 794 cases of SCD were identified. The cases were predominantly male (85.4%), with the mean age of 49.4 ± 13.9 years old. The causes of SCD were coronary artery disease (CAD; n=555, 69.8%), followed by structurally normal heart (n=113, 14.2%), cardiomegaly (n=81, 10.2%), cardiomyopathy (n=12, 1.5%), myocarditis (n=11, 1.4%), hypertensive heart disease (n=10, 1.2%), valvular heart disease (n=8, 1%), and congenital heart disease (n=4, 0.5%). The deceased in group 1 (SCD with CAD) had the highest mean of 53.3 ± 12.5 years old, followed by group 2 (SCD with non-CAD causes; 41.3 ± 13.0 years

* Corresponding Autor (ผู้ประพันธ์บรรณกิจ), Email: Sakda.sat@mahidol.edu

old), and group 3 (SCD with structurally normal heart; 38.7 ± 11.0 years old). Group 1 and group 2 have the mean BMI over 25 (25.4 ± 5.1 and 26.8 ± 7.5, respectively). While the mean BMI in group 3 is 23.0 ± 3.4. There is a statistical significance in difference between the mean heart weight in group 1 (433.5 ± 106.1 grams), group 2 (458.6 ± 121.6 grams), and group 3 (311.7 ± 65.3 grams). This study reveals the causes of adult SCD in a metropolitan area in Thailand. CAD is the leading cause of SCD in every age group. Unexplained SCD or SCD with structurally normal heart in individuals between 18-35 years old, accounting for one-third of cases.

Keywords: Sudden Cardiac Death, Forensic Autopsy

บทคัดย่อ

การตายอย่างเฉียบพลันจากหัวใจเป็นภาวะที่พบได้บ่อยทั่วโลก แต่ข้อมูลเกี่ยวกับภาวะนี้ในประเทศแถบเอเชียตะวันออกเฉียงใต้ยังมีน้อย ผู้วิจัยได้ทำการทบทวนรายงานการผ่าศพทางนิติเวชศาสตร์ที่โรงพยาบาลศิริราชซึ่งเป็นโรงพยาบาลขนาดใหญ่ที่สุดในเขตกรุงเทพฯ ตะวันตก โดยผู้วิจัยได้รวบรวมข้อมูลจากรายงานการชันสูตรผู้ตายที่อายุมากกว่า 18 ปีระหว่างปี 2018 ถึง 2020 ได้แก่ อายุ, เพศ, ดัชนีมวลกาย , สภาพแวดล้อมการตาย, น้ำหนักหัวใจ, พยาธิสภาพของหัวใจ, และสาเหตุการตาย ผู้วิจัยพบการตายอย่างฉับพลันจากหัวใจจำนวน 794 ราย ซึ่งส่วนใหญ่เป็นเพศชาย (85.4%) และมีอายุเฉลี่ย 49.4±13.9 ปี สาเหตุการตายที่พบมากที่สุด ได้แก่ โรคหลอดเลือดแดงหัวใจ (n=555, 69.8%), ตามด้วย การตายที่หัวใจปกติ (n=113, 14.2%), หัวใจโต (n=81, 10.2%), กล้ามเนื้อหัวใจผิดปกติ (n=12, 1.5%), กล้ามเนื้อหัวใจอักเสบ (n=11, 1.4%), โรคหัวใจจากความดันโลหิตสูง (n=10, 1.2%), โรคของลิ้นหัวใจ (n=8, 1%), และโรคหัวใจแต่กำเนิด (n=4, 0.5%). ผู้ตายในกลุ่มที่ 1 (โรคหลอดเลือดแดงหัวใจ) มีอายุเฉลี่ยสูงสุดคือ 53.3 ± 12.5 ปี ตามด้วยกลุ่มที่ 2 (การตายจากโรคหัวใจอื่น) คือ 41.3 ± 13.0 ปี และกลุ่ม 3 (ผู้ตายที่มีหัวใจปกติ) คือ 38.7 ± 11.0 ปี ผู้ตายในกลุ่ม 1 และ 2 มีดัชนีมวลกายมากกว่า 25 คือ 25.4 ± 5.1 และ 26.8 ± 7.5 ตามลำดับ ในขณะที่กลุ่ม 3 มีดัชนีมวลกายเฉลี่ย 23.0 ± 3.4 น้ำหนักหัวใจเฉลี่ยในผู้ตายทั้ง 3 กลุ่มมีความแตกต่างอย่างมีนัยสำคัญทางสถิติ โดยกลุ่ม 1 มีน้ำหนักหัวใจเฉลี่ย 433.5 ± 106.1 กรัม กลุ่ม 2 มีน้ำหนักหัวใจเฉลี่ย 458.6 ± 121.6 กรัม และกลุ่ม 3 น้ำหนักหัวใจเฉลี่ย 311.7 ± 65.3 กรัม งานวิจัยนี้แสดงสาเหตุของการตายอย่างฉับพลันจากหัวใจในเขตเมืองของประเทศไทย โรคหลอดเลือดหัวใจตีบเป็นสาเหตุการตายที่สำคัญในทุกช่วงอายุ การตายที่ไม่สามารถหาสาเหตุได้หลังการผ่าศพหรือการตายที่มีหัวใจปกติพบได้หนึ่งในสามในกลุ่มผู้ป่วยอายุระหว่าง 18-35 ปี

คำสำคัญ: การตายอย่างฉับพลันจากหัวใจ, การผ่าศพตรวจทางนิติเวชศาสตร์

INTRODUCTION

Sudden cardiac death (SCD) has been defined as "a natural, unexpected fatal event occurring within one hour from the onset of symptoms in a healthy subject or in one whose disease was not so severe as to predict an abrupt outcome" (Goldstein, 1982). This description effectively characterizes the circumstances surrounding many deaths observed within the community or in emergency departments. However, this definition becomes less adequate when applied to the realm of forensic pathology. Whereas autopsies are required for individuals whose deaths were unobserved, occurred during sleep, or took place at an unknown time before their bodies were discovered. Under these circumstances, it is probably reasonable to assume that death was considered sudden if the deceased was known to be in good health 24 hours prior to death (Virmani et al., 2001).

SCD is one of the most common causes of death worldwide. The World Health Organization (WHO) estimated that approximately 17.7 million people die from cardiovascular diseases each year (Thomas et al., 2018). An approximate of 300,000-400,000 SCDs occur in the United States each year (Stecker et al., 2014). There is limited data regarding SCD characteristic in Southeast Asian countries. The Department of Forensic Medicine at the Faculty of Medicine Siriraj Hospital, Mahidol University, is a state organization responsible for conducting post-mortem examinations in collaboration with police investigators. A forensic autopsy will be performed whenever the cause of death cannot be established after an initial on-site postmortem examination. The incidence and epidemiological data of individuals with sudden unexpected deaths outside of hospitals may be distinct from those typically collected from hospital records or emergency setting. The insights gained from examining heart diseases and pathological features through post-mortem investigations can be valuable for developing diagnostic methods and preventive measures against future SCD.

MATERIAL AND METHOD

Study design

This study was a cross-sectional retrospective review of forensic autopsy report. The data collection process was performed after approval by the Institutional Review Board of the Faculty of Medicine Siriraj Hospital (Approval number 577/2565).

The forensic autopsy reports of individual older than 18 years old during January 2018 – December 2020 were reviewed. Sudden unexpected death is defined as death in an otherwise healthy person within 1 hour after onset of symptoms, or when unwitnessed, within 24 hours after the person was last seen in good health. Cases will be considered as SCD for analysis if the cause of death is related to cardiac conditions. Data regarding age, sex, prior clinical history (if available), and autopsy findings were collected. Cases were excluded if they were external examination only. Bodies with advanced decomposition were also excluded due to incomplete data. The heart weight of >350 grams was considered cardiomegaly in this study.

Statistic analysis

Statistical analysis was performed with IBM SPSS statistic software version 22 (IBM Armonk, NY, USA). Continuous variables were compared using unpaired Student's t-test. Categorical variables were compared using chi-square test. The differences between 3 groups were assessed by one way ANOVA tests. The p-value of less than 0.05 was considered statistical significance.

RESULTS

Demographic data

During 2018 – 2020, a total of 2,601 sudden unexpected death bodies were transported to Siriraj Hospital for forensic autopsy (approx. 867 cases/year). After initial review, 1,477 cases were excluded due to non-cardiac causes of death , and 330 cases were excluded for being external examination only, advanced decomposition, and under 18 years of age. SCD criteria were identified in 794 cases (**Figure 1**). The deceased were predominantly male (85.4%). The age ranged from 18-92 years old (mean 49.4 ± 13.9 years

old). SCD was most prevalent in individuals >50 years old, followed by middle-aged (> 35-50 years old), and individual younger than 35 years old (**Figure 2**).

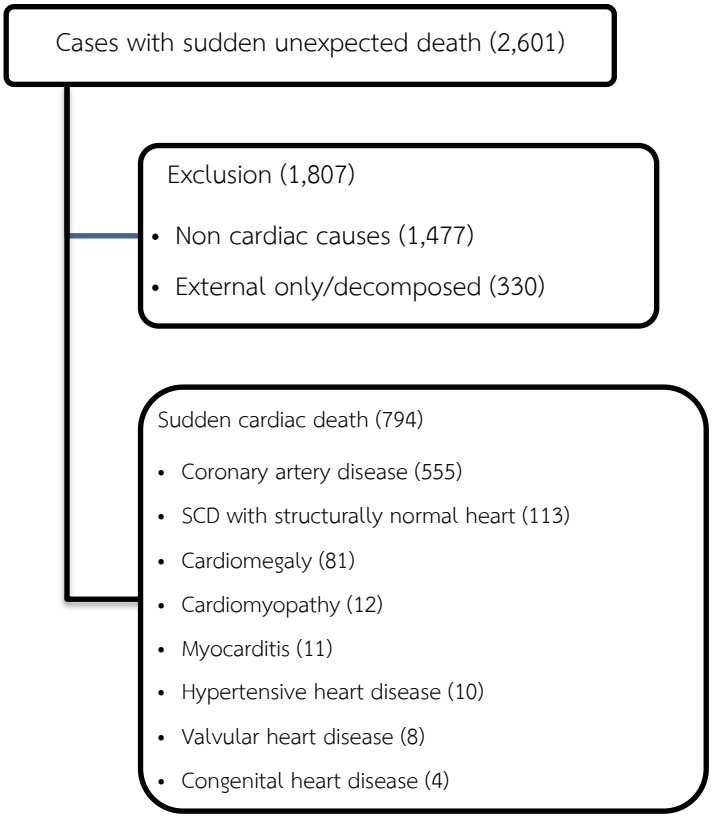

Figure 1: Causes of SCD during 2018-2020

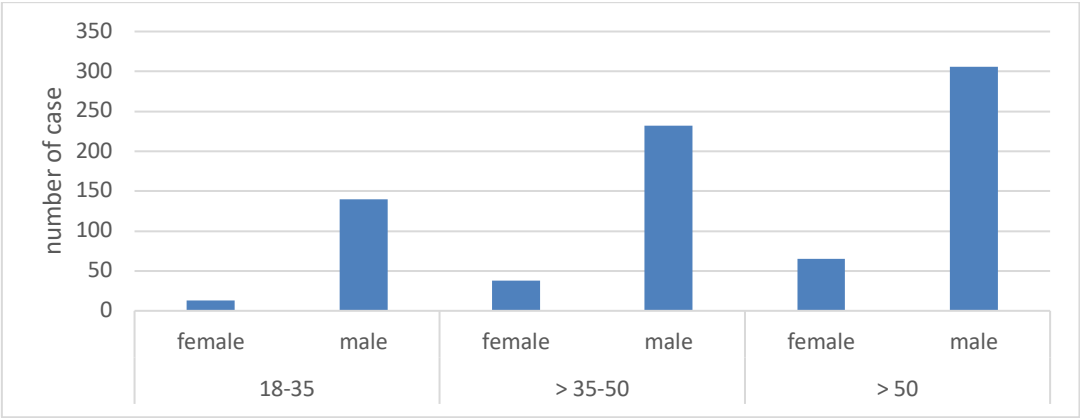

Figure 2: Distribution of SCD cases in each age group

Most of the circumstance during SCD were unknown to the investigators. The reported activities when SCD occurred included sleeping (18%), at rest (9 %), during light activity (9%), and during exercises (4%). The most common reported symptom from the deceased was chest pain, followed by seizure, dyspnea, syncope, abdominal pain, and vomiting.

Cause of death

The most common cause of death in this series was coronary artery disease (CAD; n=555, 69.8%), followed by structurally normal heart (n=113, 14.2% of cases). Other causes of death include cardiomegaly (n=81, 10.2%), cardiomyopathy (n=12, 1.5%), myocarditis (n=11, 1.4%), hypertensive heart disease (n=10, 1.2%), valvular heart disease (n=8, 1%), and congenital heart disease (n=4, 0.5%), as shown in **Figure 1**. The pie chart for causes of death in all age group is portrayed in **Figure 3**.

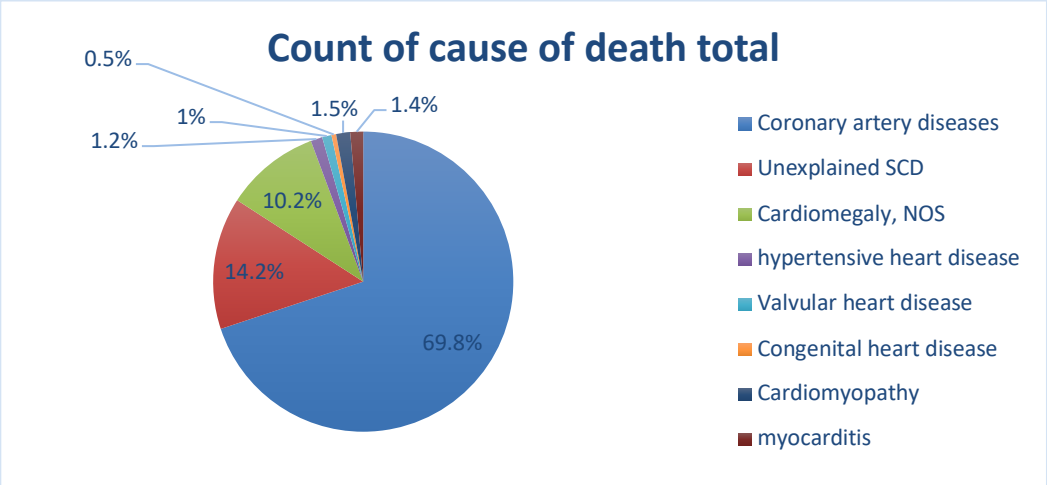

Figure 3: Causes of SCD

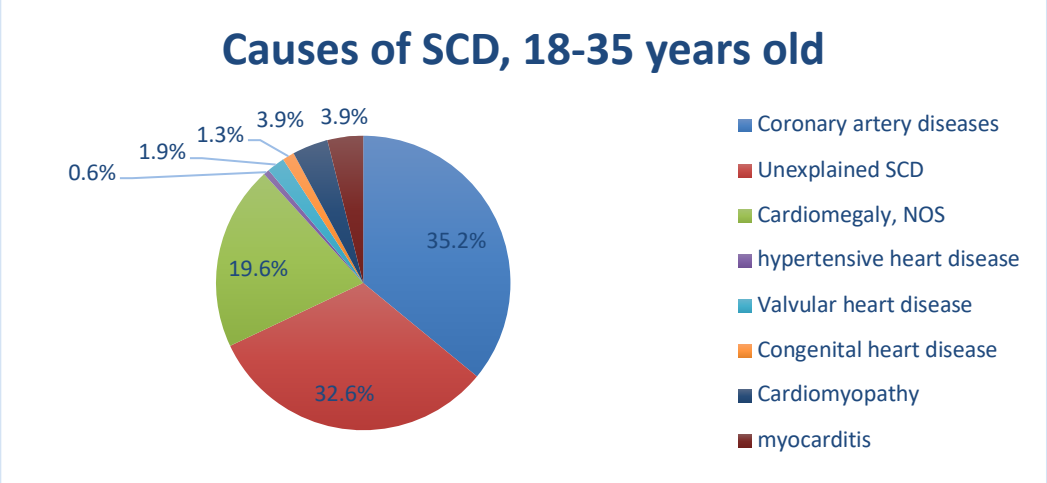

Figure 4: Causes of SCD in deceased between 18-35 years old

CAD is the most common cause of death in every age group, as shown in **Figure 4-6**. It noteworthy that SCD with structurally normal heart (unexplained SCD) is more prevalent in the younger age group.

Cardiomegaly (heart weight >350 grams) was rendered as cause of death in 81 (10.2%) cases. It should be noted that prior history of hypertension was not known to the forensic pathologist at the time of the autopsy. Otherwise, there was 10 cases of hypertensive heart disease in this series, which can be higher if the history of hypertension was acknowledged.

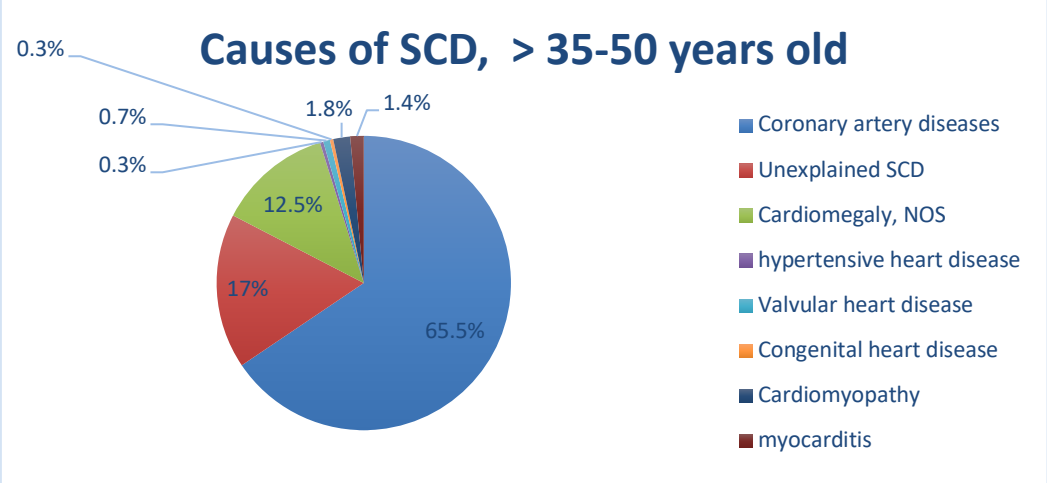

Figure 5: Causes of SCD in deceased between > 35-50 years old

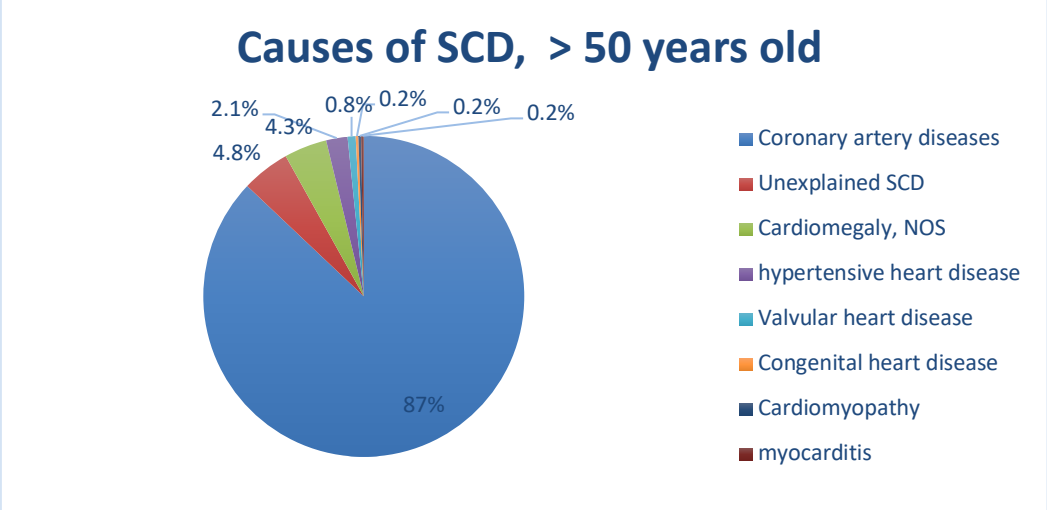

Figure 6: Causes of SCD in deceased between > 50 years old

Twelve cases of cardiomyopathy were identified (1.5%). There were 6 cases of hypertrophic cardiomyopathy (HCM), 5 cases of dilated cardiomyopathy (DCM) and 1 case of arrhythmogenic cardiomyopathy (AC), aka. arrhythmogenic right ventricular cardiomyopathy (ARVC).

For further data analysis, causes of death were categorized into 3 groups, including Group 1: CAD (n=555, 69.8%), Group 2: non-CAD SCD (n=126, 15.9%), and Group 3, SCD with

structurally normal heart (n=113, 14.2%). The results comparing the mean age, BMI, and heart weight are shown in **Table 1**.

Table 1: Characteristic data from each cause of death group

	All cases	Cause of death			p-value*
		Group 1 CAD	*Group 2* Non-CAD causes	*Group 3* SCD with structurally normal heart	
Age (mean ± SD)	49.4 ± 13.9	53.3 ± 12.5	41.3 ± 13.0	38.7 ± 11.0	<0.001
BMI (mean ± SD)	25.3 ± 5.5	25.4 ± 5.1	26.8 ± 7.5	23.0 ± 3.4	<0.001
Heart wt. (mean ± SD)	420.2 ± 113.3	433.5 ± 106.1	458.6 ± 121.6	311.7 ± 65.3	<0.001

*p-value was calculated using one-way ANOVA

Table 2: Distribution of SCD causes in each age group

		Cause of death			Total	p-value*
		Group 1 CAD	*Group 2* Non-CAD causes	*Group 3* SCD with structurally normal heart		
18-35 years old	Female	3 (25.0%)	5 (41.7%)	4 (33.3%)	12	0.666
	Male	46 (35.9)	39 (30.5%)	43 (33.6%)	128	
	Total	49 (35.0%)	44 (31.4%)	47 (33.6%)	140	
>35-50 years old	Female	14 (40.0%)	8 (22.9%)	13 (37.1%)	35	0.002
	Male	152 (67.3%)	41 (18.1%)	33 (14.6%)	226	
	Total	166 (63.6%)	49 (18.8%)	46 (17.6%)	261	
>50 years old	Female	54 (78.3%)	7 (10.1%)	8 (11.6%)	69	0.019
	Male	286 (88.3%)	26 (8.0%)	12 (3.7%)	324	
	Total	340 (86.5%)	33 (8.4%)	20 (5.1%)	393	
Total	Female	71 (61.2%)	20 (17.2%)	25 (21.6%)	116	0.034
	Male	484 (71.4%)	106 (15.6%)	88 (13.0%)	678	
	Total	555 (69.8%)	126 (15.9%)	113 (14.2%)	794	

*p-value was calculated using chi-square

Age

Group 1 had the highest mean of 53.3 ± 12.5 years old, followed by group 2 (41.3 ± 13.0 years old), and group 3 (38.7 ± 11.0). Statistical significance was observed in the difference between the mean ($p<0.001$). However, there was no statistically significant difference in between the group 2 and group 3.

Distribution of cause of death in each age group (18-35, >35-50, and >50 years old) is shown in **Table 2**. Using chi-square test, it was revealed in individuals between 18-35 years old, both males and females, had the same distribution of cause of death. However, in the age group >35-50 and > 50 years old, CAD was the predominant cause of death with statistical significance.

Body mass index (BMI)

Mean BMI in group 1 (25.4 ± 5.1) and group 2 (26.8 ± 7.5) are over 25. While the mean BMI in group 3 is 23.0 ± 3.4. Using one way ANOVA test, group 3 has the lowest mean BMI with statistical significance ($p<0.001$).

Heart weight

There is a statistical significance in difference between the mean heart weight ($p<0.001$) in group 1 (433.5 ± 106.1 grams), group 2 (458.6 ± 121.6), and group 3 (311.7 ± 65.3).

DISCUSSION

In this study, CAD is the most common cause of death and predominant in every age group. It has been established that CAD was accounted for 70-80% of SCD cases (Holmstrom et al., 2022). This finding is consistent with prior studies in many countries, including Canada (Ha et al., 2022), and China (Ding et al., 2017).

The main cause of CAD is predominantly attributed to atherosclerosis. As individuals age, the likelihood of developing atherosclerosis increases, especially in comparison to younger individuals and those with more pre-existing conditions, making it a significant risk factor (Palasubramaniam et al., 2019). In addition, CAD is more prevalent in males than females, consistent with previous findings that SCD cases related to CAD are more common in males (Butters et al., 2021; Rodgers et al., 2019). In this autopsy case series, SCD prevalence is higher in the elderly population, particularly those aged over 50. This finding is consistent with previous studies, where the incidence of SCD tends to increase with age (Abbas et al., 2023; Rodgers et al., 2019; Wong et al., 2019).

SCD with negative autopsy finding is present in one–third of cases in individuals ≤35 years old. In this circumstances, genetic testing for channelopathy might be warrant for causative gene identification and counseling of the remaining family member (Basso et al., 2010). In the previous study at Siriraj Hospital, whole exome sequencing was performed in 25 SCD victims, 72% (18 cases) were found to have potentially causative SUDS mutations. Including TTN and SCN5A genes (Suktitipat et al., 2017). The challenge in interpreting variants from whole exome data is insufficient information for further classification with certainty, either benign or pathogenic. In these cases a designation of variant of unknown significance (VUS) is given. This is due to an incomplete understanding of the spectrum of genomic variability and which areas of proteins are critical for normal function (Baudhuin et al., 2017). Thus, an interpretation of genetic testing requires integrated multidisciplinary communication, between forensic practitioner, the families, the clinical programs, and researchers involved in functional study, and the genetic counselor (Sampson & Tang, 2017).

In a circumstance where other cause of death was excluded, cardiac hypertrophy could be considered as the cause of death (Basso et al., 2021). As the heart weight tends to increase along with the body weight, height, BMI, and body surface area (BSA), there is no definite single cut-point for the diagnosis of cardiac hypertrophy for general population. However, due to the lack of this type of data in Thai population, the authors decided to use 350 grams, which is a general cut-point for cardiomegaly in our institution, to separate cases with cardiomegaly, NOS from negative autopsy cases. Thus, the number of negative autopsy cases might be underestimated in this study.

Twelve cases of cardiomyopathy were identified in this study. Common cardiomyopathies (HCM, DCM, and AC) were all present. Over the period of three years, restrictive cardiomyopathy (RCM) was not identified. RCM is the rarest form of cardiomyopathy in both clinical and autopsy studies. In autopsy population, evidence of RCM is hardly indicated, as the diagnosis requires physiologic assessment to demonstrate restrictive physiology.

The prevalence of myocarditis in this series is 1.3% of SCD cases. This number is much lower than that of previous autopsy studies in the US (7.4% in 20-40 years old) (Shen et al., 1995) and Italy (5.1% in both children and adult)(Passarino et al., 1997). Detailed cardiac examination and rigorous histologic examination should be performed to prevent underdiagnosis of myocarditis. If pediatric population is included in this study, the prevalence could also be higher.

Symptoms preceding SCD were largely unknown in this report, as the events were often unwitnessed and there was a delay in body recover. Therefore, the majority of cases were labeled as "unknown symptoms". SCD during sleep is very common in the Northeastern part of Thailand. There has been an effort to study specific genes related to ion channel disease in Thai population (Pitiwararom et al., 2023). Previous studies suggest that SCD events during sleep may be influenced by genetic factors, hypokalemia, thiamine deficiency, noxious agents, and emotional stress (Munger & Booton, 1990; Nimmannit et al., 1991; Pitiwararom et al., 2023; Veerakul & Nademanee, 2000). However, the postmortem genetic test was not routinely performed in Thailand, and data regarding the regional origin of the deceased were not collected.

The body habitus of individuals in Group 1 and Group 2 are indicated by higher BMI. Since these two groups tend to have more underlying medical conditions. However, due to the nature of forensic setting, this type of data was not available. Increased heart weight in both CAD and non-CAD groups were also note. This finding might indicate the chronicity of disease progression, resulting in cardiac remodeling (Nakamura & Sadoshima, 2018). While in Group 3, the pathophysiology leading to death is likely arrhythmic in nature, resulting in the finding of structurally normal heart at the autopsy.

CONCLUSION

In conclusion, this research sheds light on the prevalence and characteristic of the forensic autopsy population. However, limitations exist, including the retrospective nature of the study and its reliance on data from a single institution. Further research, especially

focusing on genetic factors and involving a broader sample, is warranted to enhance our understanding of SCD in Thailand.

REFERENCES

Abbas, R., Abbas, A., Khan, T. K., Sharjeel, S., Amanullah, K., & Irshad, Y. (2023). Sudden Cardiac Death in Young Individuals: A Current Review of Evaluation, Screening and Prevention. *J Clin Med Res*, *15*(1), 1-9. https://doi.org/10.14740/jocmr4823

Basso, C., Carturan, E., Pilichou, K., Rizzo, S., Corrado, D., & Thiene, G. (2010). Sudden cardiac death with normal heart: molecular autopsy. *Cardiovasc Pathol*, *19*(6), 321-325. https://doi.org/10.1016/j.carpath.2010.02.003

Basso, C., Michaud, K., d'Amati, G., Banner, J., Lucena, J., Cunningham, K., Leone, O., Vink, A., van der Wal, A. C., Sheppard, M. N., & Association for European Cardiovascular, P. (2021). Cardiac hypertrophy at autopsy. Virchows Arch, 479(1), 79-94. https://doi.org/10.1007/s00428-021-03038-0

Baudhuin, L. M., Leduc, C., Train, L. J., Avula, R., Kluge, M. L., Kotzer, K. E., Lin, P. T., Ackerman, M. J., & Maleszewski, J. J. (2017). Technical Advances for the Clinical Genomic Evaluation of Sudden Cardiac Death: Verification of Next-Generation Sequencing Panels for Hereditary Cardiovascular Conditions Using Formalin-Fixed Paraffin-Embedded Tissues and Dried Blood Spots. Circ Cardiovasc Genet, 10(6). https://doi.org/10.1161/CIRCGENETICS.117.001844

Butters, A., Arnott, C., Sweeting, J., Winkel, B. G., Semsarian, C., & Ingles, J. (2021). Sex Disparities in Sudden Cardiac Death. Circ Arrhythm Electrophysiol, 14(8), e009834. https://doi.org/10.1161/CIRCEP.121.009834

Ding, Z., Yang, M., Wang, Y., Wu, S., Qiu, X., & Liu, Q. (2017). Retrospective analysis of 769 cases of sudden cardiac death from 2006 to 2015: a forensic experience in China. Forensic Sci Med Pathol, 13(3), 336-341. https://doi.org/10.1007/s12024-017-9888-z

Goldstein, S. (1982). The necessity of a uniform definition of sudden coronary death: witnessed death within 1 hour of the onset of acute symptoms. Am Heart J, 103(1), 156-159. https://doi.org/10.1016/0002-8703(82)90552-x

Ha, A. C. T., Doumouras, B. S., Wang, C. N., Tranmer, J., & Lee, D. S. (2022). Prediction of Sudden Cardiac Arrest in the General Population: Review of Traditional and Emerging Risk Factors. Can J Cardiol, 38(4), 465-478. https://doi.org/10.1016/j.cjca.2022.01.007

Holmstrom, L., Juntunen, S., Vahatalo, J., Pakanen, L., Kaikkonen, K., Haukilahti, A., Kentta, T., Tikkanen, J., Viitasalo, V., Perkiomaki, J., Huikuri, H., Myerburg, R. J., & Junttila, J. (2022). Plaque histology and myocardial disease in sudden coronary death: the Fingesture study. Eur Heart J, 43(47), 4923-4930. https://doi.org/10.1093/eurheartj/ehac533

Munger, R. G., & Booton, E. A. (1990). Thiamine and sudden death in sleep of South-East Asian refugees. Lancet, 335(8698), 1154-1155. https://doi.org/10.1016/0140-6736(90)91154-3

Nakamura, M., & Sadoshima, J. (2018). Mechanisms of physiological and pathological cardiac hypertrophy. Nat Rev Cardiol, 15(7), 387-407. https://doi.org/10.1038/s41569-018-0007-y

Nimmannit, S., Malasit, P., Chaovakul, V., Susaengrat, W., Vasuvattakul, S., & Nilwarangkur, S. (1991). Pathogenesis of sudden unexplained nocturnal death (lai tai) and endemic distal renal tubular acidosis. Lancet, 338(8772), 930-932. https://doi.org/10.1016/0140-6736(91)91786-t

Palasubramaniam, J., Wang, X., & Peter, K. (2019). Myocardial Infarction-From Atherosclerosis to Thrombosis. Arterioscler Thromb Vasc Biol, 39(8), e176-e185. https://doi.org/10.1161/ATVBAHA.119.312578

Passarino, G., Burlo, P., Ciccone, G., Comino, A., Cravello, M., Iannicelli, P., & Mollo, F. (1997). Prevalence of myocarditis at autopsy in Turin, Italy. Arch Pathol Lab Med, 121(6), 619-622. https://www.ncbi.nlm.nih.gov/pubmed/9199630

Pitiwararom, R., Vongpaisarnsin, K., & Hoonwijit, U. (2023). SCN5A gene exome sequencing profile in sudden unexplained nocturnal death syndrome in Thai population. Chulalongkorn Medical Journal, 63(2). https://he05.tci-thaijo.org/index.php/CMJ/article/view/287

Rodgers, J. L., Jones, J., Bolleddu, S. I., Vanthenapalli, S., Rodgers, L. E., Shah, K., Karia, K., & Panguluri, S. K. (2019). Cardiovascular Risks Associated with Gender and Aging. J Cardiovasc Dev Dis, 6(2). https://doi.org/10.3390/jcdd6020019

Sampson, B. A., & Tang, Y. (2017). Holistic Approach to Determine Cause of Autopsy-Negative Sudden Natural Death. J Am Coll Cardiol, 69(17), 2146-2148. https://doi.org/10.1016/j.jacc.2017.01.068

Shen, W. K., Edwards, W. D., Hammill, S. C., Bailey, K. R., Ballard, D. J., & Gersh, B. J. (1995). Sudden unexpected nontraumatic death in 54 young adults: a 30-year population-based study. Am J Cardiol, 76(3), 148-152. https://doi.org/10.1016/s0002-9149(99)80047-2

Stecker, E. C., Reinier, K., Marijon, E., Narayanan, K., Teodorescu, C., Uy-Evanado, A., Gunson, K., Jui, J., & Chugh, S. S. (2014). Public health burden of sudden cardiac death in the United States. Circ Arrhythm Electrophysiol, 7(2), 212-217. https://doi.org/10.1161/CIRCEP.113.001034

Suktitipat, B., Sathirareuangchai, S., Roothumnong, E., Thongnoppakhun, W., Wangkiratikant, P., Vorasan, N., Krittayaphong, R., Pithukpakorn, M., & Boonyapisit, W. (2017). Molecular investigation by whole exome sequencing revealed a high proportion of pathogenic variants among Thai victims of sudden unexpected death syndrome. PLoS One, 12(7), e0180056. https://doi.org/10.1371/journal.pone.0180056

Thomas, H., Diamond, J., Vieco, A., Chaudhuri, S., Shinnar, E., Cromer, S., Perel, P., Mensah, G. A., Narula, J., Johnson, C. O., Roth, G. A., & Moran, A. E. (2018). Global Atlas of Cardiovascular Disease 2000-2016: The Path to Prevention and Control. Glob Heart, 13(3), 143-163. https://doi.org/10.1016/j.gheart.2018.09.511

Veerakul, G., & Nademanee, K. (2000). What is the sudden death syndrome in Southeast Asian males? Cardiol Rev, 8(2), 90-95. https://doi.org/10.1097/00045415-200008020-00005

Virmani, R., Burke, A. P., & Farb, A. (2001). Sudden cardiac death. Cardiovasc Pathol, 10(5), 211-218. https://doi.org/10.1016/s1054-8807(01)00091-6

Wong, C. X., Brown, A., Lau, D. H., Chugh, S. S., Albert, C. M., Kalman, J. M., & Sanders, P. (2019). Epidemiology of Sudden Cardiac Death: Global and Regional Perspectives. Heart, Lung and Circulation, 28(1), 6-14. https://doi.org/https://doi.org/10.1016/j.hlc.2018.08.026