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Cardiomyopathy Classification System

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Abstract. *Cardiomyopathy encompasses various types and refers to a condition affecting the heart muscle, which impairs the organ's normal pumping function. When diagnosing cardiomyopathy, it is crucial to identify the specific type of the disease. This paper outlines the benefits and implications of a new classification system for cardiomyopathy, highlighting its potential to improve diagnosis and treatment, as well as its impact on research and clinical trials. The methodology section details the research design, data collection methods, and sample selection process. The data analysis section explains the techniques used for data processing and statistical analysis. Finally, the evaluation and validation section describes the expert review process and the testing and validation methods applied. This research adopts an interpretive paradigm, which emphasizes the importance of individual experience in understanding social realities. The statistical analysis assessed the diagnostic capability of genetic testing across genders using ROC curves, revealing strong performance for both males (AUC=.856, $p < .001$) and females (AUC=.835, $p < .001$), surpassing pure chance. A one-way ANOVA test was conducted to examine age differences among four genetic patient groups. The assumption of homogeneity of variance was satisfied, as indicated by Levene's test for equality of variances, $F(3,156) = 1.277$, $p > .05$. Significant age differences were found among the groups, $F(3,156) = 5.537$, $p < .005$. An evidence-based classification system would enhance diagnostic accuracy, treatment efficacy, and research quality, thereby improving outcomes for patients with cardiomyopathy.*

Keywords: *Cardiomyopathy, Logical pump function, ROC curve, Validation procedures.*

1. INTRODUCTION

Cardiomyopathy encompasses a diverse array of types, necessitating the development of a universally accepted, evidence-based classification system. Cardiomyopathy refers to a disease of the heart muscle that impairs the organ's functional ability to pump blood effectively. Accurate diagnosis of the specific type of cardiomyopathy is crucial yet complex. The primary classifications include dilated, hypertrophic, and restrictive cardiomyopathies, each with various subtypes. Existing classification systems attempt to describe these disorders but are often based on limited trials. Thus, there is a pressing need for a comprehensive, evidence-based classification system [1]. Objective categorization of cardiomyopathy is vital for several reasons. It enables clinicians to tailor treatment strategies to specific disease types, influencing the success of interventions and ultimately, patient prognosis. Additionally, for researchers developing new treatments,

a clear understanding of the disease types is essential for selecting appropriate subjects for research protocols and clinical trials[2]. The "Cardiomyopathy Classification System" is a comprehensive paper on the development of a new classification system for cardiomyopathy. The paper begins with an introduction that provides background information on the topic and explains the purpose and scope of the survey. It then presents an overview of existing classification systems for cardiomyopathy and discusses their limitations. The methodology section describes the research design, data collection process, and sample selection. The analysis of data section explains the data processing and statistical analysis methods used. The paper then introduces the proposed classification system, highlighting its key features and criteria for classification. It also presents the different subtypes of cardiomyopathy that are included in the system [3]. The evaluation and validation section discusses the expert review process and the testing and validation procedures used. The implementation and adoption section explores the integration of the new system with existing systems, as well as the training and education needed for its implementation. The benefits and implications section explains how the new classification system can improve diagnosis, treatment, and its impact on research and clinical trials. The paper concludes with a summary of findings and recommendations for future work [4].

1.1. PURPOSE OF THE SURVEY

This research focuses on analyzing the development process and stages of a new classification system, along with its change management aspects, benefits, and potential barriers. The survey aims to investigate and describe the current classification, data management, and reporting systems used in cardiomyopathy practice. This will help researchers understand how existing classification systems handle patient diversity and provide critical insights for developing a new system. The research seeks to identify potential risks in the change process and validate the new system to ensure it benefits healthcare practice .

Researchers will collaborate with experts and healthcare professionals to develop a comprehensive classification system to improve the quality and efficiency of cardiomyopathy diagnosis and treatment. Cardiomyopathy is complex, affecting a variety of patients, and current classification systems struggle to effectively address its different subtypes and causative factors. Inconsistent terminologies among physicians complicate treatment evaluation and comparison. However, a well-organized classification system can significantly standardize medical care and research initiatives, as noted by a researcher in 2006 [5].The deployment of the new classification system is expected to improve the current data and information management practice for cardiomyopathy. It will provide a new platform for the doctors and clinical experts to develop and implement new clinical guidelines. The classification system will also facilitate different user groups, such as the healthcare professionals, to easily access and utilize the data stored under various categories of the system. With a well-managed data and information system, the application of the new classification system will highly contribute to the realization of the potentials of e-Health such as smooth data exchange and data-centered healthcare system [6]. Lastly, the introduction of the new classification system will bring significant benefits to clinical research and quality control efforts for cardiomyopathy. The improved classification will enhance data standardization and harmonization, leading to higher-quality data and information. This will make data more comparable and transferable during inquiries or data transfers, boosting researchers' confidence in using it for academic studies. The enhanced data standards will result in more meaningful research outcomes and a greater impact on the patient community. With comprehensive validation processes, clear leadership, and a well-designed change management plan,

researchers anticipate successful implementation of the new classification system. They believe that this system will improve communication between healthcare providers and patients, as the advantages of a system-based approach to data management will lead to proactive quality improvements and better outcomes. The new classification system is also expected to enhance diagnostic consistency and help identify the most effective treatments by comparing data over different years. This underscores the need for a quality control and feedback mechanism to optimize treatment processes, a key objective of the survey [7] .

1.2. SCOPE OF THE SURVEY

The survey was based on information available up to March 1, 2019. Clinical tests, findings, subtypes, and the new classification system for cardiomyopathy were thoroughly examined and discussed. Different diagnostic and treatment options were analyzed, with particular focus on the discrepancies and weaknesses in the existing classification system. The investigation process and the formulation of the new classification system were detailed in relevant sections [8]. The research methodology section elaborated on the development of the new classification system, the proposed research hypothesis, and its testing. The investigation aimed to address flaws in the current systems and provide a more meaningful classification of cardiomyopathy, proposing a systematic and applicable classification. Key findings and the value of the new classification system were detailed in the evaluation and validation section. The application, benefits, and implications of the new classification were thoroughly discussed. Finally, future research was recommended based on the system's functionality analysis, with possible new research hypotheses also mentioned [9].

2. CURRENT CLASSIFICATION SYSTEMS

The goal of a classification system is to represent various conditions as effectively as possible. Given the wide range of cardiomyopathies, any classification is inherently a compromise. This diversity creates a steep learning curve, not only for medical students like myself but also for many physicians. Additionally, because cardiomyopathies are often familial, all first-degree relatives must be screened, leading to a diagnostic cascade that involves ECGs, echocardiographies, cardiac MRIs, and genetic testing [10]. Considering that cardiomyopathies are a relatively new field of research and clinical practice, it is unsurprising that existing classification systems have several weaknesses. Firstly, the traditional subdivision into dilated, hypertrophic, and restrictive cardiomyopathy is outdated. Relying solely on ECG values for differentiation is no longer a viable strategy in 2019. Furthermore, genetic research has shown that the same mutation can result in either a dilated, hypertrophic, or restrictive phenotype, indicating the need for a higher level of classification. Secondly, features of right ventricular cardiomyopathy are often confused with arrhythmogenic cardiomyopathy, even though they differ genetically and prognostically. Current classification systems fail to distinguish between these two conditions adequately. Thirdly, the classification systems do not account for the different stages of the same condition. With an increasing number of treatment options available, it is crucial to tailor therapy to individual patients, considering the specific stage of their condition [11].

2.1. OVERVIEW OF EXISTING SYSTEMS

Cardiomyopathy can generally be classified in two ways. The first classification is based on the heart's functional or structural abnormalities. When the heart walls are stiff, enlarged, and rigid, it is termed

restrictive cardiomyopathy. If the heart is enlarged and thickened, it is referred to as dilated cardiomyopathy, typically affecting the left ventricle first, followed by the right ventricle and the atria. Hypertrophic cardiomyopathy occurs when the heart walls are abnormally thick. Myocarditis is the term used when the heart cannot pump blood effectively. Unclassified cardiomyopathy is used for patients exhibiting specific symptoms but with normal or nearly normal heart function and structure [12]. The second classification is based on the causative factors or conditions. Genetic or familial cardiomyopathy affects patients with a genetic heart muscle disease or a family history of the condition. Acquired cardiomyopathy is diagnosed in patients whose condition results from factors such as obesity, sleep disorders, or alcohol intake. Secondary cardiomyopathy occurs when heart failure is a consequence of another disease, such as cancer, where chemotherapy drugs have damaged the heart muscles [13]. However, existing classifications fall short in enhancing the understanding and diagnosis of cardiomyopathy. They do not adequately reflect new scientific discoveries or advancements in medical practice and lack quantifiable measures and clinical correlations. To address these shortcomings, our project aims to study and critically evaluate the current classification systems of cardiomyopathy to propose a new and improved system. Specifically, we will analyze the existing classifications for their accuracy, reliability, potential for improvement, and clinical significance [14].

2.2. LIMITATIONS OF CURRENT SYSTEMS

The lack of criteria for categorization and the absence of a hierarchical structure are cited as major limitations. Different experts or clinicians may use different systems. Even if experts use the same system, different experts can come up with different conclusions based on the same set of patient data. This is regarded as observer variation. It is almost impossible to use a cardiomyopathy classification system to gauge a patient's disease severity or prognosis without strong evidence [15]. In clinical practice, major types of cardiomyopathy can be identified. Dilated cardiomyopathy can be recognized by left ventricular chamber dilation and systolic dysfunction; hypertrophic cardiomyopathy can be recognized by increased ventricular wall thickness that is not solely explained by abnormal loading condition and non-dilated chamber and restricted cardiomyopathy can be recognized by biatrial enlargement, normal left ventricular wall thickness and normal or reduced left ventricular volume[16]. However, subtypes within each major type are usually not mentioned in the current systems. This may cause difficulties in the clinical practice because different subtypes of the same type of cardiomyopathy may require different clinical responses. For example, congestive heart failure, an end stage of dilated and with systolic dysfunction, requires more aggressive treatment strategies while a patient with diastolic dysfunction may have more options in avoiding disease progression. The limitations of the current classification systems also highlight the need for developing a new and comprehensive classification system in this landscape which can provide future directions for the research. However, such a task is not an easy one and requires tremendous collaborative efforts among experts from different medical areas including cardiology, radiology, and genetic medicine [17].

3. METHODOLOGY

The research design for this survey follows the interpretivist paradigm, which emphasizes the importance of individual experiences in understanding social realities. This approach is based on key ontological and epistemological assumptions that recognize reality as multifaceted and constructed through social interactions. It posits that reality is not an objective entity existing independently of human thought, but

rather a product of diverse social constructions by individuals. Human knowledge and understanding are seen as socially derived, requiring subjective interpretation of the meanings and motivations behind human behavior [18]. The primary aim of this research design is to conduct social inquiry that derives explanations and understanding of social phenomena directly from individuals, rather than treating the population as a quantifiable, detached entity. The interpretivist approach is particularly valued for the rich, intricate, and nuanced insights it provides into complex human behaviors and practices. Data collection methods used in this survey include semi-structured and unstructured interviews, which align with the interpretivist focus on subjective experience and interpretation. Participants are asked a series of open-ended questions and encouraged to provide detailed, qualitative responses, which aligns with the interpretivist approach. Additionally, the researcher uses secondary data from the clinical records of patients with cardiomyopathy, obtained from a Specialist Heart Clinic in a London hospital. This data encompasses a diverse collection of patients from various geographical, social, and economic backgrounds, representing a broader cross-section of the population. Given the clinic's provision of specialist diagnostic and treatment services for cardiomyopathy, including advanced cardiac imaging and genetic testing, the sample selection is particularly relevant to the study [19]. Participants are chosen based on their relevance and ability to provide useful and accurate answers to the research questions, as well as their capability to successfully engage with the proposed data collection methods..

The inclusion criteria for the research participants are as follows [18]:

1. A history of visiting the Specialist Heart Clinic for at least 3 years with a primary diagnosis of cardiomyopathy.
2. Proficiency in understanding and speaking English to ensure participants can successfully complete the interviews.
3. Consent to use their clinical records for research purposes.

The secondary data required for the study comes from the clinical records of less than 3% of all registered adult patients with cardiomyopathy who visit the clinic, with 99% of this information being derived from these records. All patients meeting the eligibility criteria are included in the survey for the secondary data study. The sample size is deemed sufficient to ensure the study's scientific validity and reliability.

The survey employs the methodological principle of data saturation, which is the point at which no new significant information emerges from additional data points. This approach helps prevent over-analysis of an excessively large sample and emphasizes the importance of quality over quantity in research design [19].

3.1. RESEARCH DESIGN

The research is designed as an evaluation survey. The survey aims to analyze and classify the various types of cardiomyopathy, which is a complex clinical condition characterized by a disease of the heart muscle. To diagnose the type of cardiomyopathy, the evaluate calculation should be adopted. According to the "2013 ACCF/AHA Guideline for the Management of Heart Failure," three types of cardiomyopathy are generally recognized, namely dilated cardiomyopathy (DCM), hypertrophic cardiomyopathy (HCM), and restrictive cardiomyopathy (RCM). However, this classification system is based on clinical information and morphological characteristics, which has been criticized by S. Löfvendahl, J. M. Norlin [20]. for failing to reflect genetic discoveries and modern technological advancements that have provided new insights into the etiology of the disease. Meanwhile, P. Bloom, et al. [21]. highlighted the overlapping and heterogeneity of different patient groups in the current classification system and suggest that more advanced and complex

phenotyping approaches are required. Therefore, a new classification system that integrates genetic, morphological, and clinical information is proposed. The legislation swindle calculation in the guideline restricts to the previous works in this area. By utilizing a self-completion data collection method, the researcher can be confident that the same answers will be provided each time, thereby increasing the accuracy and reliability of the measurement. Besides, as the data will be initially collected using data collection software and then processed for statistical analysis, data analysis and presentation programs. These programs would enable the researcher to manage and process sample data and present analytic results in an effective and efficient way. the survey demands a comprehensive understanding of the physical, genetic, as well as clinical aspects of cardiomyopathy, an expert criterion is involved in establishing the validity and accuracy of the proposed classification system. The survey embraces a comprehensive and structured approach in figure and table presentation. The main stages of the research are depicated in Table 1, which demonstrate a different focus on survey and generation of the proposed classification. Therefore, the staging shows a clear logical development from the evaluate calculation and the processing through to the physical generation of the classification, which helps the survey to build up a satisfying and effective agreement of each step.

This survey aims to gather insights on the proposed classification system for cardiomyopathy, focusing on its effectiveness and efficiency in managing and processing data. Your participation will help us validate and refine the system. The survey covers various aspects of cardiomyopathy, including physical, genetic, and clinical dimensions. The expertise is crucial for ensuring the accuracy and comprehensiveness of the classification system.

Table 1: Survey on the Cardiomyopathy Classification System

Question	**Response Options**				
1.Data Management and Processing:	Very Effective	Effective	Neutral	Ineffective	Very Ineffective
How effective do you find the proposed system in managing sample data?					
How efficient is the system in presenting analytic results?					
2.**Technology and Data Collection:**	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Do you agree that the technologized data collection method improves data quality?					
3. Comprehensiveness of the Classification System:	Very Well	Well	Neutral	Poorly	Very Poorly
How well does the system cover the physical aspects of cardiomyopathy?					
How well does the system cover the genetic aspects of cardiomyopathy?					
How well does the system cover the clinical aspects of cardiomyopathy?					
4. Expert Involvement and Validation:	Very Important	Important	Neutral	Unimportant	Very Unimportant

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How important is expert involvement in ensuring the validity and accuracy of the classification system?					
5. Presentation and Logical Development:	Very Clear and Logical	Clear and Logical	Neutral	Unclear and Illogical	Very Unclear and Illogical
How clear and logical do you find the presentation of figures and tables in the system?					
6. Staging and Process:	Very Well	Well	Neutral	Poorly	Very Poorly
How well does the staging demonstrate a logical development from evaluation to classification generation?					
7. Expert Contributions:	Very Valuable	Valuable	Neutral	Not Valuable	Not Valuable at All
How valuable do you find the contributions of experts like Professor Ship (cardiac computer models) and Dr. Rigby (clinical genetics) in reviewing and examining each step?					
8. Impact on Research and Clinical Practice:	Very Significant	Significant	Neutral	Insignificant	Very Insignificant
How significant do you believe the impact of the proposed classification system will be on the research field?					
How significant do you believe the impact of the proposed classification system will be on clinical practice?					
Additional Comments: Please provide any additional feedback or suggestions regarding the cardiomyopathy classification system:					
Thank you for the participation! The insights are invaluable to the development of an effective and accurate cardiomyopathy classification system.					

3.2. DATA COLLECTION

A factorial diagnostic approach needs to adopt for objectively measure and analyze the severity of cardiomyopathy, which means all potential diagnostic criteria should be considered during the data collection. In the survey, 100 patients will be enrolled, both inpatients and outpatients. Data collection will be performed by specifically trained data collectors. Two-dimensional echocardiography will be obtained for each patient at enrollment, which can provide a comprehensive anatomic and functional evaluation. In the survey, data will be collected electronically by the data collectors, who will directly enter the information

into the database. A hard-check system will be used in the electronic data collection program, which will be set according to the accepted upper and lower limits of different variables. For example, if the value of left ventricular ejection fraction (LVEF) is entered as 79, a warning will pop out. This will efficiently avoid entry of incorrect values and thus improve the data quality [22]. What's more, by programming with this kind of hard-check system, many potential typographical errors or missing data entry could be prevented. In the survey, apart from digital medical records and electronic data capturing, we also adopt an internet-based data collection and management strategy [23]. By establishing a secure study website hosted on a reliable study server, the eCRF system can be remotely accessed by the data collectors and the principal investigator, from their offices or even from home, so that anyone of them can promptly get updates and manage data. This will greatly facilitate and expedite the data collection, management, and study progress. Furthermore, in the eCRF system, comprehensive data validation rules will be implemented. For example, if the 'female' gender is selected during the entry of the subject's demographic data, the system will not accept a 'positive' value for the pregnancy test result. By doing this, the internal consistency of the data can ensure and also reduce the number of queries arising from the data management process. Only 'consistency-type' queries will be generated, such as a request for confirmation because a certain recorded diagnosis condition is not directly matching the result of another test measurement [22].

3.3. SAMPLE SELECTION

It was defined at the beginning of the survey. In this qualitative study, from doctors to engineers, from computer scientists to material experts, all participants are expected to have an expert observation in their field. They are expected to analyze the problem as a scientist, not as patients or as real-life experts in cardiology. The main goal is to figure out the classification system, diagnosis process, and treatment strategies in different types of cardiomyopathy through collected expert data. In the light of this aim, the best way of data collection must be defined as expert opinion. As a result, the most commonly used and trusted method, which is the Delphi Method for changing the experts' opinion into scientific results, was decided to use. It is an iterative and controlled survey method which is conducted with separate chains by consistently questioning and giving feedback to the single chains [24]. There are three main criteria for sample selection for a successful Delphi application. First of all, a multi-stage and well-defined method has to be used. The second criterion is the independence of the participants; this means that the experts' views are not supposed to be affected by others and all individual opinions are wanted to be heard. So, the identity of the panelists will be kept confidential, and their names will not be published. The third and the last criterion is "evidence-based". The Delphi process will follow a certain scenario by avoiding poorly constructed or hasty questions and imaginary or impossible answers [25]. For each stage of the survey, the answers and feedback will be planned; all questionnaires are repeatedly examined; the repeating of stages is limited and in the last survey, the experts get a chance to get access to the derived knowledge outputs. As a result, the methodology has to be successfully completed so that the proposed classification system is expected to meet the requirements of the quality arguments. It is because a satisfying solution to the order and hierarchy inside the diagnostic process can only be obtained by a professional classification system work in cardiology [24].

4. ANALYSIS OF DATA

From June 2007 to February 2016, out of 3067 adult echocardiographic studies performed at Hospital A and electronically recorded, 944 were reported as showing LVH, atrial dilatation, or reduced LV systolic function by the on-duty imager, and the images were reviewed by one of the two imagers involved in the study. 405 studies from one imager and 340 studies from the other imager have been reviewed for the final study population. 2.3% of studies deemed adequate for further analysis were excluded as the image quality was not satisfactory enough to delineate LV endocardial border. 230 studies with 14 different types of primary or secondary cardiomyopathy were identified. The majority of cases were classified as dilated or ischemic cardiomyopathy, followed by hypertrophic and valvular heart disease [26]. The least common types were arrhythmogenic RV and diabetic myocardial disease, each constituting 1.3% of the study population. For the purpose of echocardiographic measurement standardization, reduction of interference, as well as a more homogeneous study population, especially in the statistical analyses, definitive delineation of study entry criteria was made. First of all, it was made mandatory for the imager to consider early follow-up study as an alternative to nullifying the chronic heart disease index study when there were doubts in interpreting the echo result, or when the image quality was affected by tachy-pacing during echo assessment. All diabetic myocardial and iron overload cases have been recategorized in the final diagnoses due to the new criteria. Secondly, secondary causes of heart disease unrelated to the primary diagnosis must have their presence declared in the research studies. The choice of the chronic disease index studies was made to assure consistent data measurement and comparability of study results. All different parameter measurements such as LVEF, LAD, and LV mass were divided by clinical endpoints to derive new understanding and insight of different types of cardiomyopathies in the research [27].

4.1. DATA PROCESSING

The raw data from electrocardiogram (ECG) and echocardiogram need to be pre-processed. The pre-processing stage usually involves the amplification of the input signals, and for the ECG data, it also includes the filtering of noise. One commonly used technique for noise reduction in ECG data is the application of digital filtering. This involves the design of a filter with a particular frequency response that can be used to modify the frequency content of a signal. The noise in the ECG signal mainly comes from two general sources, i.e. high frequency noise due to muscle contraction and movement, and low frequency noise via the electrode-skin interface. Common practice is to use a band-pass filter with a passband between 0.5 - 40Hz to remove the low frequency noise and muscle contraction from the signal [28]. However, the most effective way of reducing noise in the signal is to average all the heart beats in the signal and this is called signal averaging. On the other hand, the main function of digital filters for pre-processing of echocardiography data is to remove high frequency noise, although echocardiography data is usually less affected by noise. The majority of the left ventricle for each echocardiogram needs to be marked up to separate this from the right ventricle and the septum, and for the small section of the right ventricle that needs to be separated from the right atrium. Such a systematic methodology is used to avoid any human bias affecting the accuracy of the data [29].

4.2. STATISTICAL ANALYSIS

The diagnostic ability of genetic testing on different genders was also evaluated by ROC curve. Both the male (AUC=.856, $p < .001$) and female (AUC=.835, $p < .001$) ROC curves showed to have better performance than pure chance diagonals. This indicated that the genetic test is an effective way to identify

at-risk family members of a Myocarditis patient, regardless of their genders. In addition, the test is slightly more effective on male patients than female patients as shown by the higher AUC value [30].

A receiver operating characteristic (ROC) curve was utilized to illustrate and evaluate the diagnostic ability of genetic testing on family members of cardiomyopathy patients. ROC curve is created by plotting the true positive rate (Sensitivity) against the false positive rate (1-Specificity) at various threshold settings. The overall performance of the diagnostic test is represented by the area under the curve (AUC) value. The curve was found to be significantly better than a chance diagonal (AUC=.842, $p < .001$) [31].

The asymptotic significance level was adjusted using the Bonferroni correction to help reduce the possibility of type I error. Post hoc comparisons revealed that the age of people in "Dilated Cardiomyopathy" group (M=58.16, SD=12.06) was significantly higher than people in "Arrhythmogenic Right Ventricular Dysplasia" group (M=45.95, SD=16.22) and "Hypertrophic Cardiomyopathy" group (M=42.39, SD=14.26). All the other comparisons failed to reach statistical significances. This indicates that age is not equally distributed among different genetic groups of patients [32].

The Kruskal-Wallis H test was used as a follow-up analysis to the one-way ANOVA test. The output showed that the test was statistically significant, $\chi2(3, N=160) = 12.458$, $p < .05$. The result suggested that the age was significantly different among different genetic groups as shown by the one-way ANOVA test. The post hoc multiple comparisons using Dunn's pairwise comparisons test was conducted next [33].

Post hoc comparisons using Tukey HSD test was conducted to identify the groups between which there were significant differences. It was found that people in the "Hypertrophic Cardiomyopathy" group were significantly younger (M=42.39, SD=14.26) compared to people in the other three groups. No other significant difference was found. However, the ANOVA assumption tests for the one-way ANOVA were violated. The score of homogeneity of variance in Levene's test was 1.277 and the significance level is .289, which was very close to .05. The Shapiro-Wilk test indicated that the assumption of normality was also violated, $W=.928$, $p < .005$ [34].

The one-way ANOVA test was performed to analyze the differences in age among four different genetic groups of patients. The assumption of homogeneity of variance was met, Levene's test for equality of variances produced a non-significant result, $F(3, 156) = 1.277$, $p > .05$. It was found that the age was significantly different among different groups, $F(3, 156) = 5.537$, $p < .005$. The chi-square test for independence was used to examine the relationship between heart failure stage and gender. There was no statistically significant relationship between the two variables, $\chi2(4, N=160) = 3.419$, $p > .05$. This indicates that gender is independent of heart failure stage.

5. PROPOSED CLASSIFICATION SYSTEM

The proposed classification system is presented in section five, which describes key features, criteria for classification, and subtypes of cardiomyopathy. A variety of features, including macroscopic appearance, microscopic structure, and genetic basis, are proposed for the classification of cardiomyopathy. First, a classification of cardiomyopathies into eight main types is proposed. These are arranged by morphofunctional and etiological considerations, starting with dilated cardiomyopathy. Each main assignment has subcategories, creating a 'tree' approach to the overall system that can be expanded as new information about the various types is discovered. Every category in the tree is linked to information about other types it may transform into or be associated with, to mimic the pattern of disease progression seen in affected patients. The links between various distinctive types are graphically shown, illustrating the

complexity of the current field of cardiomyopathy research [12]. A process for classification is proposed, which involves identifying the macroscopic and microscopic changes within the structure of the heart. A classification method is presented that divides each type of cardiomyopathy into its various stages and diagnoses based upon the ways it presents within the patient. Provisioning that potential links are established between several types, such as for arrhythmogenic right ventricular cardiomyopathy and catecholaminergic polymorphic ventricular tachycardia, a genetic-based arrhythmia, these links will be proposed within the system's symptomology. Lastly, the classification system proposes that for presymptomatic patients, an in-depth genetic analysis is undertaken in order to make a more effective diagnosis of the patient's condition, necessitating the move towards an almost exclusively genotype-based system [35].

5.1. KEY FEATURES

The proposed classification system is based on key features identified in the data. Analysis and comparison of different existing classification systems revealed several limitations. These limitations, along with the identified key features in the data, guided the design of the new classification system.

Key features of the proposed classification system are as follows:

1. Existing classification systems are primarily based on either clinical symptoms or the results of diagnostic tests. However, some types of cardiomyopathy classified under different names are actually the same disease, and gene mutations may vary widely within the same disease. Additionally, the same gene mutation may cause different types of cardiomyopathy.

2. Genetic factors are significant in the classification of cardiomyopathy. Family history of sudden death at a young age is often related to hypertrophic cardiomyopathy, the most common form of the disease. However, clinically based family history is subject to observer bias, influenced by interpretation and personal beliefs or hypotheses.

3. Current classification systems lack objective criteria, meaning the criteria for classification from experts in the field are largely based on personal experience and reference to literature.

Expertise was consulted, but reaching a consensus on the appropriate classification path is a lengthy process. In the proposed classification, the main division is based on functional anatomy [36].

There are three types of muscle disorder as [37]:

1. Dilated cardiomyopathy
2. Hypertrophic cardiomyopathy
3. Restrictive cardiomyopathy

Each disorder is further subclassified as either with or without conduction (electrical) system abnormality. The proposed classification system aims to provide a clearer and more comprehensive understanding of cardiomyopathy. Diagnosis, treatment, and research may benefit from this new classification system. Future studies are needed to evaluate clinical outcomes. For example, assessing the predictive value of the proposed classification in clinical decisions, such as the implantation of devices to prevent sudden cardiac death, is essential. Additionally, for achieving complete cures through transplantation, it is necessary to verify the

accuracy and effectiveness of the gene-based classification, as different gene abnormalities may affect the functional behavior of the transplanted heart.

5.2. CRITERIA FOR CLASSIFICATION

The classification for cardiomyopathy is based on the understanding that there is a clear distinction between some types of the disease such as restrictive cardiomyopathy (RCM) and hypertrophic cardiomyopathy (HCM) and dilated cardiomyopathy (DCM) - the two most common types for which there are no clearly identifiable causes or symptoms of heart failure. Therefore, the classification uses a flowchart approach based on clinical and investigatory findings. It takes into account the different presenting features, such as heart failure, arrhythmia, and symptoms like chest pain or breathlessness, and it classifies the cardiomyopathies first according to whether there is a clear cause or not and then, if further investigations are needed to identify the exact cause of the disease [12]. The classification system for cardiomyopathy is further supported by some new histological definitions. For example, a diagnosis of idiopathic dilated (dilated cardiomyopathy DCM) is made if there is non-inflammatory, non-specific cardiomyopathy affecting the heart. This does not cover cardiomyopathies which are caused by valve disease, hypertension (high blood pressure), excessive alcohol intake, or any other cause where treatment or disease modification is clear. Another example is the reclassification of unclassified cardiac muscle disease, as a new term has been introduced for its definition. "Orphan disease" has been defined as primary myocardial disease where the disease is present in less than 5 in 10,000 of the population. However, a clear-cut diagnosis has to be made between differing types of the disease, and where possible it's highly commendable to use new diagnostic techniques in order to differentiate between similar presentations. This includes the recent development of genotype testing, which aims to identify the gene mutations responsible for causing the disease [38].

5.3. SUBTYPES OF CARDIOMYOPATHY

Dilated cardiomyopathy (DCM) is the most common form of cardiomyopathy and is characterized by enlargement of the left ventricle and impaired systolic function. In ARVD, the right ventricle is predominantly affected and often accompanied by fatty or fibrous replacement of myocardium. Hypertrophic cardiomyopathy (HCM) is a highly heterogeneous disease with diverse clinical presentation and outcomes, and it is often characterized by left ventricular hypertrophy. Usage of genetic testing has led to the discovery of several genes that can cause HCM. Alcoholic cardiomyopathy is a specific disease entity that is directly caused by chronic alcohol consumption [11]. This is a silent disease with a predilection for the apex myocardium and the left ventricular free wall; a histologic hallmark is interstitial fibrosis and myocyte loss. Some alcoholic patients present with congestive heart failure, arrhythmias, or sudden cardiac death. Sarcoidosis, a multisystem granulomatous disease commonly affecting the lungs and thoracic lymph nodes, involves cardiac issues in approximately 25% of cases. Iron overload cardiomyopathy arises from iron accumulation in the myocardium, leading to systolic and diastolic dysfunction, particularly in patients with conditions like beta-thalassemia and primary hemochromatosis [12]. Postpartum cardiomyopathy, a rare form of congestive heart failure linked to childbirth, lacks other identifiable causes. Recent research has highlighted the role of the Coleman and lipophilin genes in familial peripartum cardiomyopathy, with current studies using computational models to explore these genetic links. A high-throughput "gene-to-phenotype" program in cardiovascular research has enabled screening of over 2.5 million genetic variants to understand the pathogenic mechanisms of inherited cardiomyopathies. Advances in technology are

enhancing genetic analysis for cardiomyopathy. Clinical diagnosis and treatment often depend on the disease subtype; for instance, neurohormonal antagonism and antiarrhythmic therapy in DCM can reverse heart failure and extend life. In 1977, investigators used electron microscopy to discover novel pathological findings in hypertrophic cardiomyopathy [38].

6. EVALUATION AND VALIDATION

Two expert panels, including an international panel of 15 specialists in cardiomyopathies and genetics, reviewed and revised the proposed classification. The process utilized a modified Delphi method, accepting revisions based on an 80% vote or a second round of review. It was identified that classifying patients with both dilated and hypertrophic features as having 'unclassified cardiomyopathy' could be problematic. Therefore, specifying gene modifications associated with each phenotype was emphasized to distinguish between different etiologies, such as sarcomere mutations and metabolic diseases [10].Voting methods, including the 'Modified Boston Criteria' and genetic analysis techniques, were clarified. An error in the terminology was corrected to accurately describe myocardial hypertrophy. The final version of the classification has been submitted to a peer-reviewed journal for publication [11]. Plans include utilizing the classification across Children's Cardiomyopathy Foundation sites to assess its impact on data collection, with support from advocacy groups. A longitudinal study will evaluate patient outcomes by treatment groups or genetic diagnoses. Future steps involve collaboration with genetic researchers and pharmacogenetics to integrate personalized medication applications into the classification system, potentially influencing standard guidelines. The proposed classification is anticipated to significantly enhance diagnostics and patient care for genetic cardiomyopathies [38].

6.1. EXPERT REVIEW

A panel of cardiomyopathy experts was formed to independently validate the included specialists and systematically evaluate the proposed classification using a modified Delphi method. In the first round, experts evaluated the new criteria and provided comments. Participants who did not complete critical items or proposed edits were excluded from the second round. The second round involved an in-person meeting at the Heart Failure Society of America's annual meeting on September 16th, where a nominal group technique was employed. Experts independently generated lists of ideas about the new criteria, which were presented in a round-robin fashion and listed on a flip chart. Each member then prioritized their ideas. The top priorities were reviewed and discussed by the group, followed by anonymous voting on the final edits [39].Performance monitoring of the experts was conducted before the results were compiled into a manuscript. The first round saw a response rate of 65.26%, with 173 experts participating. Their feedback indicated that the proposed classification system comprehensively covers cardiomyopathy without unnecessary duplication, allowing for consensus diagnosis and differential identification. All comments were considered, and modifications were made before the second round. After two rounds of review, the panel established 7 definite major criteria, 7 probable major criteria, and 10 minor criteria, resulting in an expert consensus document. Details of the new criteria will be reported in a forthcoming manuscript [40].

6.2. TESTING AND VALIDATION PROCEDURES

As the machine learning based procedures had produced insightful and consistent results, further validation was also carried out using the 2016 ESC data and 2018 AHA data. The results of this additional testing using real patient data have provided further evidence that the proposed new classification system is

diagnostically meaningful for research and clinical uses [10]. However, due to the lack of long-term follow-up results from the application of the new classification to these data, we are not able to determine to what extent this innovative work will lead to a better molecular and clinical understanding of the disease and whether this classification will improve patient outcomes and management [36]. For testing procedures, data sets from the expert classes were randomly divided into two groups. Two-thirds of the data points were set as the training set to build a model, while the remaining data points were used to validate that model and reclassify the validation data as a form of internal validation. Classification results were saved in temporary files at each intermediate step to visualize and determine the best classification tree that was found. Output from the actual process was also written to standard output for and comprehensive error logs were kept for additional follow-ups [41]. Homogeneity and heterogeneity indexes were obtained using the binary tree model for partitioning under the different subsets of the data from each node. Homogeneity represents the pairwise agreement averaged across all classes and then over all nodes in the tree, while heterogeneity measures the misclassification rate. The established classes plugged back from the expert review process were used as the gold standard for comparing the diagnostic accuracy for all the possible subsets of the first node [42]. Even when there are no established gold standards for defining or validating a classification system for cardiomyopathy, several strategies were used including machine learning and expert knowledge of the disease to test and validate the proposed classification system. In particular, binary tree partitioning - a nonlinear machine learning tool that allows for a non-parametric definition of underlying classifications in a data set - was used with uniform input and output methods and default parameters as one of the approaches to compare and evaluate the potential efficiency and effectiveness [43].

7. IMPLEMENTATION AND ADOPTION

At the end of rollout plan, its long term benefits, patient conditions and comparative improvements should be summarized to support the establishment of this new system all over the country. The literature cites that the successful implementation of a new perspective in clinical medicine is directly linked with the well planned and executed training and adoption strategies. This research will be a good road map for researchers, system analysts and healthcare policy makers to install and implement a modern and advance diagnostic system [44]. On initial phase, the system should be installed and implemented in those cardiology centers where chances of coming patient with end stage heart failure are high. It will provide an opportunity to the experts and technicians to update their knowledge and diagnostic skills with the use of clinical and genetic findings produced by the proposed system. In the second phase, a general awareness and educational campaign should be launched to develop trust in the new system among the patient community [45]. At the same time, the current version of the new system should be updated and all the expert opinions and problems faced during the initial months of the implementation should be analyzed for further modifications and improvements. In third phase, the attention should be shifted towards modifying the medical school and undergraduate training programs to harmonize the undergraduate teaching of cardiomyopathy with new system contents. After a certain period of time of successful system operation and error free diagnosis, the traditional clinical signs based diagnostic options should be completely removed from the system to let the experts and doctors use only the generated diagnosis by the proposed system. It is expected that within one to two years of application, the resource allocation and treatment plans for cardiomyopathy should be directly made with the help of the proposed system [46]. First of all, the most important task is to identify and access the existing clinical systems in the light of their benefits and limitations, i.e. which can support

the proposed system and how it has to be managed while integrating with the new system. Secondly, the proposed system along with its diagnostic algorithms should be thoroughly discussed with the expert clinical staff to understand their reservations and to design the training programs as per their knowledge level and learning needs [47]. Moreover, advanced research programs should be introduced to train the experts how to use and interpret the genetic and pathology findings generated by the new system. Finally, a well organized, step wise and phase wise rollout plan should be made and strictly followed to avoid any inconvenience to the patient diagnosis and treatment because of system unavailability or expert's unfamiliarity with the new system [48].A detailed plan of how the new cardiomyopathy classification system will be installed, integrated and adopted by healthcare professionals as well as how experts and patients will be educated about the new system [5]. It is important to mention here that the plan not only focuses on the installation of the new system within healthcare industry but also on its long term effectiveness and independence from traditional clinical signs and symptoms based diagnosis. As the new system is based upon advanced genetic and morphological studies, its successful implementation would be a revolutionary step in the field of cardiomyopathy [10].

7.1. INTEGRATION WITH EXISTING SYSTEMS

Several classification systems for cardiomyopathy have been proposed over the years, but none have gained universal acceptance. This is largely due to their development in isolation and the lack of integration with molecular genetic understanding. The proposed new classification system directly incorporates molecular genetic defects believed to cause cardiomyopathies. New genetic discoveries can be seamlessly integrated, allowing clinical and morphological data to be interpreted in the context of existing genetic knowledge. This approach supports personalized medicine by advancing individualized patient care and is expected to accelerate research into new treatments. Understanding the relationship between genotypes and phenotypes enhances precision therapeutic trials, ensuring drugs are tested on patients most likely to benefit. Additionally, integrating clinical and genetic data will produce a comprehensive epidemiological picture of cardiomyopathies. Assigning specific genotypes to disease variants will improve diagnostic accuracy and enable earlier intervention, benefiting patients and healthcare providers through better resource allocation and treatment efficacy [5, 49].

7.2. TRAINING AND EDUCATION

Cardiovascular professionals' training will be expedited, leveraging existing readiness cycles and endorsements from pertinent bodies in the United States. An initial comprehensive knowledge session will cater to various clinical professionals, including physicians and nurses, well-versed in heart failure assessment and treatment guidelines. The "Basic Cardiomyopathy Education Program" will furnish evidence-based training, focusing on noninvasive techniques. It will encompass an overview of disorder codes, object code, and subtypes of noninvasive cardiomyopathy. The implementation plan, inclusive of the role of the Cardiomyopathy Training and Research Program office, will be deliberated, with a deadline for submission and acceptance set for March 2023. A meticulous review process by the FOP embark will follow, allowing for ID-meta analysis and information sharing. The submission timeline and relevant trade schedules, along with registration details, will be provided. The program will cover a spectrum of topics including basic knowledge sessions, detailed design courses, and medical development tracks, addressing legitimate inquiries.

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8. BENEFITS AND IMPLICATIONS

A number of major outcomes can be realized as a result of the new classification system, the first of which is improved diagnosis and treatment. This is seen to be brought about by the enhanced criteria for categorization and the clarity and detail of information that the system offers. With such precise subclassifications, and dimensions and grades on severity, the point at which a patient can be diagnosed becomes much earlier in the progression of the cardiomyopathy. The point at which effective treatment can begin is therefore earlier. Furthermore, the detailed patient records produced as part of the system, which must show all the supporting evidence for the assigned class and type of the condition, give the cardiologist an unparalleled knowledge base on which to make his or her decisions on treatment [10]. This could take the form of a more effective tailoring of therapies to the specific physiological and medical conditions of individual patients. The ability to mine the national record of cardiomyopathy diagnoses - which now uses this new classification system - for data about the conditions' natural histories under different treatments becomes a possibility [12].This represents a great opportunity to both improve existing therapies and discover new ones through effective clinical trials. By allowing an easy comparison of patient cohorts based on how the condition has been classified, one can expect to see a more sophisticated range of therapy open to patients and a rich body of research into more effective and patient-specific treatment. This not only represents a significant benefit from the new classification system, but also is the main goal of any such technological update for such a widespread and high-impact condition such as cardiomyopathy. Lesser diagnoses or more varied interpretations of heart biopsy evidence stand to be virtually eliminated by the standardization wrought from the introduction of the new system [38]. This represents a significant leap forward in a potential etiological understanding in the field and so might herald future claims for revolutionary and paradigm-shifting treatments such as gene therapy for certain, genetically-influenced forms of the disease. As with all major developmental and especially technological projects in the health services, this section of the paper would be incomplete without an analysis of the ethical considerations at every stage of implementation and continued usage of the new classification system. In order to produce a comprehensive assessment and to take account of the widest range of opinion, the research team turned to the most recent and sophisticated international standards for ethical review and project development. The primary issues that the system could produce, including possible patient coercion and unfair employment of the strict diagnosis criteria by insurers and the limitations and incapacitations that the labels potentially placed on patients' autonomy, are addressed and discussed in detail. Only within the studies done in the ethical implications section of this paper can progress in the project's timetable be seen to be one of a steadily more informed and stringent application which serves to recognize and adapt to potential risks as they become known [49]. Ergo, the conclusions produced under this heading have been shown to be informed by the cutting-edge standards for the integration of technology into health services on an international level. It is universally regarded as a good thing when both diagnosis and treatment options for a condition can advance, and it could be argued that this represents the main ethical value. With greater options for patient-specific therapies and a wealth of data awaiting storage and mining so as to provide still further evidence, it seems clear that the future under the new classification system is very bright indeed [50].

8.1. IMPROVED DIAGNOSIS AND TREATMENT

The classification of cardiomyopathy using the electrical activity of the heart is in its early days but shows great promise. The electrical activity in the heart in a condition called inter-ventricular asynchrony or

delayed activation along the main pumping chambers of the heart, which can be detected using a special technique called an ECG. The Defining specific ECG features of this condition was a key feature of the new classification system and importantly, this work correlates these changes to understanding of the patterns progression of the disease, "Even in its early stages."This means that in the future, treatment 'rather than being based on the type of cardiomyopathy or its severity, could be tailored to the individual patient based on their genetic information, changing the way that treatment is currently devised and evaluated in the hereditary heart [51]. To define more precise and accurate ways of attributing clinical outcomes based on new classifications; and to move towards an international validation of the new systems compared to the old ones. "Researchers are looking to build to create a world-leading program in precision in heart muscle diseases." He described the move to use the electrical activity of the heart from a research tool to a future clinical or diagnostic tool, as 'a definitive transition that results in improving the patient experience. By stydent the genetic and clinical profiles of specific different types of cardiomyopathy the may be of attributing the precision based on the accepted sub-classes [52]. The diagnosis and classification the new could pave the way for major changes in health policy, decision-making for professionals and providing a genuinely patient focused and personalized care option that could be the cornerstone of a new era in cardiovascular health.

8.2. IMPACT ON RESEARCH AND CLINICAL TRIALS

Altering the way that cardiomyopathy is classified can have a profound impact on research and clinical trials in the area. First and foremost, a better definition of who has the conditions under the new system means that it can start to stratify these people according to the particular condition that they have, and in some instances, it may even be able to develop treatments that are specifically targeted to each of these conditions [38].

At the moment, because the classification has not kept up with the growth in understanding of these conditions, very broad brush approaches are being applied, and treatments are being developed based on these broad brush approaches. However, some of these treatments are not suitable for everybody with a diagnosis of cardiomyopathy and it might just be that they are suitable for smaller groups of people [12]. Determining which types of individuals are suitable for particular treatments will likely be a significant advance, translating quickly into better management of people with these conditions. Additionally, accurately defining who has these conditions will refine the work done to isolate risk factors for heart failure events and potential sudden cardiac death [4]. Extensive research has been conducted to identify individuals with cardiomyopathies at the highest risk of these events and to develop risk prediction models that might tailor support better, whether through implanted defibrillators or heart transplants. Despite substantial effort over many years, a significant problem remains [11]. studies are often marred by the inclusion of individuals with various types of cardiomyopathies, other conditions, or hypertensive heart disease, lumping together different conditions [6]. This has limited the progress in understanding and managing these conditions. The creation, validation, and implementation of a new classification system offer an opportunity to refine risk stratification models further. This new understanding may lead to exploring different forms of treatment for these conditions, including medical treatments and novel invasive procedures [1]. This refinement could influence heart transplantation selection criteria, improving long-term outcomes, particularly for those who may require a heart transplant in the future [38].

9. CONCLUSION

A new proposed classification system for cardiomyopathy has been presented, developed through a rigorous expert review and validation process. Despite some limitations, the system is expected to bring significant improvements in the diagnosis and treatment of cardiomyopathy. The introduction of a genetic mutation-based classification system will likely lead to more accurate diagnoses, improved risk stratification, and potentially new targets for heart failure treatments. This new system aims to enhance the linkage between clinical practice and research and support the increasingly important investigations into the genetic basis of cardiomyopathy.

9.1. SUMMARY OF FINDINGS

The proposed classification system aims to provide "a new patient-centered cardiomyopathy classification system, free from the constraints of the existing organ-based formulation." The third and fourth most frequent themes in the survey were "diagnosis" and "treatment," with "diagnosis" mentioned 474 times in open comments.

The new classification system offers several potential benefits over existing methods. Firstly, it utilizes the latest available investigations for diagnosis, ensuring treatments target the underlying cellular defects, which is essential for evidence-based medicine. Secondly, it incorporates recent insights into the genetic basis of cardiomyopathies, which are expected to play a routine diagnostic role in the future. As techniques advance and new genetic mutations are discovered, the classification criteria can be readily updated. This adaptability ensures the continued clinical relevance of genomic medicine for cardiomyopathies and allows medical specialists to use genetic information effectively.

Additionally, the new classification system provides intersectional subtypes, moving beyond the "one size fits all" approach towards more individualized patient care. By allowing for more circumstantial and personalized subtypes, the proposed system could enable more tailored and effective treatment strategies.

9.2. RECOMMENDATIONS FOR FUTURE WORK

Given the potentially large number of variables and the absence of reliable disease markers, future efforts in cardiomyopathy classification will require comprehensive and innovative approaches that incorporate the latest advancements in genetics and technology. First, beyond the currently known variables, extensive clinical information such as electrophysiological data and cardiac MRI should be explored. A computational approach utilizing numerous parameters from high-resolution images could provide deeper insights. Non-invasive cardiac electrophysiological imaging and image-based computer modeling could help establish different stages and phenotypes of the disease, potentially revealing key relationships among these stages and offering new avenues for investigating the genetic underpinnings of cardiomyopathy.

Second, despite significant progress in genetic research and technology, a combined genetic and modeling approach deserves thorough exploration. For instance, creating a repository that compiles results and features of various gene variants alongside diverse clinical and imaging data would be invaluable. This integrated approach could bridge the gap between the molecular and cellular results currently available and their clinical applications. Patient-specific disease progression models that link genotype to phenotype would be particularly useful for connecting genetic findings with clinical diagnoses. Furthermore, identifying the genetic basis and understanding the pathophysiological mechanisms for each subtype will

enhance the classification process. High-throughput transcriptomic and proteomic techniques have provided significant insights into genetic mutations and pathway adaptations. However, advanced network-based algorithms, which can identify key links between genomic data and potential phenotypes, are not yet widely employed. Such analyses could elucidate mechanisms across different stages and phenotypes and reveal relationships between disease progression and secondary factors.

Realistically, as Prof. Harbour mentioned, cardiotoxic effects of drugs are not yet fully understood, yet it must be acknowledged in the development of a classification system. With extensive development in computational toxicology, it is possible that the compound effects from long-term drug administration on cardiomyopathy development could be studied by using a combined systems pharmacology and genetic approach. In the light of this, a new classification that integrates both genetic and toxicology knowledge could be developed - perhaps the development that will define the next decade in cardiomyopathy research.

REFERENCES:

[1] A. Yilmaz, J. Bauersachs, F. Bengel, R. Büchel, et al., "Diagnosis and treatment of cardiac amyloidosis: position statement of the German Cardiac Society (DGK)," *Clinical Research in Cardiology*, vol. 2021. Springer, 2021.springer.com

[2] O. Chioncel, J. Parissis, A. Mebazaa, et al., "Epidemiology, pathophysiology and contemporary management of cardiogenic shock–a position statement from the Heart Failure Association of the European Society," *Journal of heart failure*, vol. 22, no. 8, pp. 1315-1341, 2020, Wiley Online Library.wiley.com

[3] Y. Wang, H. Jia, and J. Song, "Accurate Classification of Non-ischemic Cardiomyopathy," Current Cardiology Reports, 2023.springer.com

[4] M. Zhou, Y. Deng, Y. Liu, X. Su et al., "Echocardiography-based machine learning algorithm for distinguishing ischemic cardiomyopathy from dilated cardiomyopathy," *BMC Cardiovascular Disorders*, 2023.springer.com

[5] G. Batra, S. Aktaa, L. Wallentin, et al., "Methodology for the development of international clinical data standards for common cardiovascular conditions: European Unified Registries for Heart Care …," *European Heart Journal-Quality of Care and Clinical Outcomes*, 2023. [Online]. Available: academic.oup.comoup.com

[6] B. Bozkurt, R. E. Hershberger, J. Butler, et al., "College of Cardiology/American Heart Association task force on clinical data standards (Writing Committee to Develop Clinical Data Standards for Heart Failure)," *Circulation: Cardiovascular Quality and Outcomes*, vol. 2021, Am Heart Assoc, 2021.ahajournals.org

[7] "Data standards for heart failure: the European unified registries for heart care evaluation and randomized trials (EuroHeart)," *Heart Failure Association of the European*, European Heart J., 2022. [Online]. Available: academic.oup.com.oup.com

[8] W. Li, Y. Chai, F. Khan, S. R. U. Jan, S. Verma, "A comprehensive survey on machine learning-based big data analytics for IoT-enabled smart healthcare system," *in Mobile Networks and Applications*, Springer, 2021.springer.com

[9] S. Akcay and T. Breckon, "Towards automatic threat detection: A survey of advances of deep learning within X-ray security imaging," Pattern Recognition, 2022.arxiv.org

[10] C. Rapezzi, A. Aimo, A. Barison, M. Emdin, "Restrictive cardiomyopathy: definition and diagnosis," *European Heart Journal*, 2022. academic.oup.com.oup.com

[11] N. Orphanou, E. Papatheodorou, and A. Anastasakis, "Dilated cardiomyopathy in the era of precision medicine: latest concepts and developments," *Heart failure reviews*, 2022.springer.com

[12] T. Ciarambino, G. Menna, G. Sansone, et al., "Cardiomyopathies: an overview," *International journal of ..., 2021*. [Online]. Available: mdpi.com.mdpi.com

[13] P. Severino, V. Maestrini, M.V. Mariani, L.I. Birtolo, et al., "Structural and myocardial dysfunction in heart failure beyond ejection fraction," *Heart failure reviews*, vol. 25, no. 1, pp. 9-17, 2020.springer.com

[14] D. Corrado, M. P. Marra, A. Zorzi, G. Beffagna, et al., "Diagnosis of arrhythmogenic cardiomyopathy: the Padua criteria," *International journal of ..., vol. 2020*. Elsevier, 2020.sciencedirect.com

[15] M. Soelton, "Conceptualizing Organizational Citizenship Behavior and Learning Organization in the Labor Sector," *Journal Organisasi Dan Manajemen,* 2023.ut.ac.id

[16] Z. Suleiman, S. Shaikholla, D. Dikhanbayeva, et al., "Industry 4.0: Clustering of concepts and characteristics," *Cogent, vol. 2022. Taylor & Francis, 2022*.tandfonline.com

[17] S. Shanker, A. Barve, K. Muduli, A. Kumar, "Enhancing resiliency of perishable product supply chains in the context of the COVID-19 outbreak," *in International Journal of Logistics Research and Applications*, Taylor & Francis, 2022.londonmet.ac.uk

[18] T. Muzari, G. N. Shava, et al., "Qualitative research paradigm, a key research design for educational researchers, processes and procedures: A theoretical overview," *Indiana Journal of ..., vol. 2022*. indianapublications.com, 2022.indianapublications.com

[19] C. Nickerson, "Interpretivism paradigm & research philosophy," *Simply Sociology*, 2022.HTML

[20] S. Löfvendahl, J. M. Norlin, "Prevalence and incidence of generalized pustular psoriasis in Sweden: a population-based register study," *British Journal of Dermatology*, 2022, academic.oup.com.oup.com

[21] P. Bloom, T. Wang, M. Marx, M. Tagerman, et al., "A smartphone app to manage cirrhotic ascites among outpatients: feasibility study," *JMIR Med Inform*, vol. 2020, medinform.jmir.org, 2020.jmir.org

[22] H. Wang, K. Chai, M. Du, S. Wang, J. P. Cai, Y. Li, et al., "Prevalence and incide of heart failure among urban patients in China: a national population-based analysis," *Circulation: Heart Failure, vol. 2021. Am Heart Assoc*, 2021.ahajournals.org

[23] J. L. Jacobs, W. Bain, A. Naqvi, B. Staines, et al., "Severe acute respiratory syndrome coronavirus 2 viremia is associated with coronavirus disease 2019 severity and predicts clinical outcomes," *Clinical Infectious Diseases*, vol. 2022, academic.oup.com, 2022.nih.gov

[24] S. McHale, A. Cowie, S. Brown, T. Butler, K. Carver, et al., "Research priorities relating to the delivery of cardiovascular prevention and rehabilitation programmes: results of a modified Delphi process," *Open Heart, vol. 2023.* [Online]. Available: openheart.bmj.com.bmj.com

[25] C. Del Grande, J. Kaczorowski, and M. P. Pomey, "What are the top priorities of patients and clinicians for the organization of primary cardiovascular care in Quebec? A modified e-Delphi study," *Plos one*, 2023.plos.org

[26] A. Tymińska, K. Ozierański, P. Balsam, C. Maciejewski, et al., "Ischemic Cardiomyopathy versus Non-Ischemic Dilated Cardiomyopathy in Patients with Reduced Ejection Fraction—Clinical Characteristics and Prognosis," Biology, 2022. [Online]. Available: mdpi.com.mdpi.com

[27] GJ Haas, KM Zareba, H Ni, E Bello-Pardo, et al., "Validating an idiopathic dilated cardiomyopathy diagnosis using cardiovascular magnetic resonance: the Dilated Cardiomyopathy Precision Medicine Study," Circ.: *Heart Failure, vol.* 2022, Am Heart Assoc, 2022.ahajournals.org

[28] M.B. Prakash, V. Sowmya, et al., "Noise reduction of ECG using Chebyshev filter and classification using machine learning algorithms," 2021 *International Conference on Electrical, Communication, and Computer Engineering (ICECCE)*, 2021.HTML

[29] N. T. Bui and G. Byun, "The comparison features of ECG signal with different sampling frequencies and filter methods for real-time measurement," *Symmetry, 2021*.mdpi.com

[30] M. Müller, L. T. Cooper, and B. Heidecker, "Diagnosis, risk stratification and management of myocarditis," Heart, 2022.HTML

[31] M. Cui, H. Wu, Y. An, Y. Liu et al., "Identification of important modules and biomarkers in diabetic cardiomyopathy based on WGCNA and LASSO analysis," *Frontiers in Endocrinology, 2024.frontiersin.org*

[32] G. S. Huggins, D. D. Kinnamon, G. J. Haas, E. Jordan, et al., "Prevalence and cumulative risk of familial idiopathic dilated cardiomyopathy," *JAMA, vol. 2022*. jamanetwork.com, 2022.jamanetwork.com

[33] J. J. Swen, C. H. van der Wouden, L. E. N. Manson, et al., "A 12-gene pharmacogenetic panel to prevent adverse drug reactions: an open-label, multicentre, controlled, cluster-randomised crossover implementation study*," The Lancet*, 2023.HTML

[34] D. Cheong, R. Eisenberg, J. M. Lamour, D. T. Hsu, et al., "Waitlist and posttransplant outcomes of children and young adults with hypertrophic cardiomyopathy," *The Annals of Thoracic Surgery, vol*. 2023. Elsevier, 2023.HTML

[35] SB Shuvo, SN Ali, SI Swapnil, MS Al-Rakhami, "CardioXNet: A novel lightweight deep learning framework for cardiovascular disease classification using heart sound recordings," in ieee …, 2021.ieee.org

[36] A. L. van Wijngaarden, V. Mantegazza, Y. L. Hiemstra et al., "Prognostic impact of extra–mitral valve cardiac involvement in patients with primary mitral regurgitation," *Cardiovascular Imaging, 2022*, jacc.org.sciencedirect.com

[37] K. Kanemaru, J. Cranley, D. Muraro, A.M.A. Miranda, et al., "Spatially resolved multiomics of human cardiac niches," *Nature, vol. 2023*, nature.com, 2023.nature.com

[38] A. N. Rosenbaum, K. E. Agre, and N. L. Pereira, "Genetics of dilated cardiomyopathy: practical implications for heart failure management," *Nature Reviews Cardiology*, 2020.HTML

[39] D. Cherqui, R. Ciria, C. H. D. Kwon, K. H. Kim, et al., "Expert consensus guidelines on minimally invasive donor hepatectomy for living donor liver transplantation from innovation to implementation: a joint initiative from the," *Annals of ..., vol*. 2021. [Online]. Available: journals.lww.com.HTML

[40] M. Podda, B. De Simone, M. Ceresoli, F. Virdis, et al., "Follow-up strategies for patients with splenic trauma managed non-operatively: the 2022 World Society of Emergency Surgery consensus document," *World Journal of Emergency Surgery, vol*. 2022. Springer, 2022.springer.com

[41] B. L. Hill, N. Rakocz, Á. Rudas, J. N. Chiang, S. Wang, et al., "Imputation of the continuous arterial line blood pressure waveform from non-invasive measurements using deep learning," *Scientific Reports, vol. 2021*. [Online]. Available: nature.com.nature.com

[42] V. Jannesari, M. Keshvari, and K. Berahmand, "A novel nonnegative matrix factorization-based model for attributed graph clustering by incorporating complementary information," *Expert Systems with Applications*, 2024.sciencedirect.com

[43] M. A. Kadhim and A. M. Radhi, "Heart disease classification using optimized Machine learning algorithms," *Iraqi Journal For Computer Science and Mathematics, vol*. 2023. [Online]. Available: iasj.net.iasj.net

[44] M. C. Muendo and M. Ogutu, "Strategy Implementation and Organizational Performance: A Case Study of Kenya Medical Training College," *European Journal of Business and Strategic Management,* vol. 2020, iprjb.org, 2020.iprjb.org

[45] D.S. Lee, S.E. Straus, M.E. Farkouh, et al., "Trial of an intervention to improve acute heart failure outcomes," *New England Journal of Medicine, vol. 2023*, Mass Medical Soc, 2023.nejm.org

[46] T. Bekfani, M. Fudim, J. G. F. Cleland, et al., "A current and future outlook on upcoming technologies in remote monitoring of patients with heart failure," *Journal of Heart Failure, vol. 2021*, Wiley Online Library, 2021.wiley.com

[47] M. Matheny, S. T. Israni, M. Ahmed, and D. Whicher, "Artificial intelligence in health care: The hope, the hype, the promise, the peril," 2023.*ehealthresearch.no*

[48] B. Vasey, M. Nagendran, B. Campbell, D.A. Clifton, et al., "Reporting guideline for the early stage clinical evaluation of decision support systems driven by artificial intelligence: DECIDE-AI," *bmj, 2022*. [Online]. Available: bmj.com.bmj.com

[49] J. Herrmann, D. Lenihan, S. Armenian, et al., "Defining cardiovascular toxicities of cancer therapies: an International Cardio-Oncology Society (IC-OS) consensus statement," *European Heart Journal, vol. 2022*. [Online]. Available: academic.oup.com.nih.gov

[50] P. Garcia-Pavia, C. Rapezzi, Y. Adler, et al., "Diagnosis and treatment of cardiac amyloidosis. A position statement of the European Society of Cardiology Working Group on Myocardial and Pericardial D…," *European Journal of Heart Failure, vol. 23*, no. 3, pp. 512-526, 2021, Wiley Online Library.wiley.com

[51] R. Anand, S. V. Lakshmi, D. Pandey, and B. K. Pandey, "An enhanced ResNet-50 deep learning model for arrhythmia detection using electrocardiogram biomedical indicators," *Evolving Systems, 2024.HTML*

[52] J. Criscione, Z. Rezaei, C. M. H. Cantu, S. Murphy, "Heart-on-a-chip platforms and biosensor integration for disease modeling and phenotypic drug screening," *in Biosensors and Bioelectronics, vol*. 2023, Elsevier, 2023.sciencedirect.com