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Original Article

The Impact of Cardiovascular Risk Factors on the Development of Heart Failure: A Longitudinal Study of Comorbidities and Treatment Outcomes

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ABSTRACT

Heart failure (HF) is a complex clinical syndrome often resulting from the cumulative impact of multiple cardiovascular risk factors and comorbidities. This longitudinal cohort study aimed to evaluate the contribution of traditional cardiovascular risk factors—hypertension, coronary artery disease, diabetes mellitus, obesity, and valvular heart disease—to the development of heart failure, and to assess treatment outcomes in patients with concurrent comorbid conditions. Using a large electronic health record dataset spanning 2015 to 2024, we analyzed data from over 10,000 individuals aged 40 and above. The findings revealed that diabetes mellitus exhibited the highest adjusted hazard ratio (HR=2.29, 95% CI: 2.10–2.49), followed by coronary artery disease (HR=2.04) and hypertension (HR=1.72), affirming their dominant role in HF onset. Moreover, comorbidities such as chronic kidney disease, anemia, chronic obstructive pulmonary disease (COPD), and atrial fibrillation were shown to significantly worsen prognosis, with chronic kidney disease presenting the highest mortality impact (HR=1.89, $p<0.001$). Diabetic cardiomyopathy was specified as a separate disease affecting the heart muscles and not simply an additional factor in cardiovascular pathologies; thus, it was detected that there is an increased prevalence of left ventricular dysfunction and myocardial fibrosis among patients with diabetes. Demand study revealed that out of the total prescriptions, diuretics with 81.5% brush used rate were most commonly prescribed but ARNIs and SGLT2 inhibitors had the highest improvements in ejection fraction and less hospitalization. These findings underscore the need for a comprehensive approach to the treatment of patients with heart failure, especially those having multiple conditions. To increase survival status as well as quality of life among the patients with heart failure, effort in risk stratification, individualised treatment and aggressive management of co morbidity should be early instigated.

INTRODUCTION

When the heart cannot pump blood and oxygen to the various organs of the body the condition known as heart failure arise. This may require the use of drugs, and sometimes even admission to hospital [1]. Heart failure is a clinical syndrome associated with ventricular dilation and reduced ejection fraction and is last phase of several other CV diseases [2]. Heart failure is an emerging issue in HC because statistics show that more than 8 million people in the USA will be affected by it by 2030 [3]. The syndrome is the state of reduced blood supply for adequate oxygen and nutrients needed for body tissues due to ineffective pumping of the heart [4]. Obesity, diabetes mellitus, coronary artery disease, high blood pressure, and valvular heart disease are some of the comorbidities that are intertwined with the development of the heart failure [5]. Heart failure presently affects 1-2% of the general population but increases up to 10% in people over the age of 70 [6]. There are more patients with HF because heart diseases are treatable and the general population is aging [7, 8]. Chronic obstructive pulmonary disease, anaemia, and renal dysfunction as well as other associated illnesses contribute to the worsening of heart failure and complicate treatment outcomes and management of the condition [9].

This is because of the fact that several trials for risk stratification to reduce the rate of progress of heart failure arising from cardiovascular risks are required due to multiple interactions [10]. Actually, hypertension continuously exerts additional pressure on the heart resulting in diastole dysfunction, left ventricular hypertrophy and heart failure [11]. Indeed, hypertension results in LV structural and functional changes reducing its ability to relax and fill properly during diastole [12]. Coronary artery disease, which is characterized by the formation of atherosclerotic plaques in the coronary arteries, not only decreases the myocardial blood flow and provokes ischaemia, infarction and negative effects on cardiomyocytes but also makes a man susceptible to heart failure. Deposition of plaque in the blood vessels that supply blood to the heart leads to coronary artery disease, the most common type of heart disease, and can result in congestive heart failure, heart attack, or chest pain [13]. Hypoglycemia is one of the major characteristics of diabetes mellitus, a disease that affects heart failure through a series of unfavorable effects outcomes on the cardiovascular system including endothelial dysfunction, microvascular disease and myocardial fibrosis [14]. Indeed, heart failure is now well known and recognized as one of cardiovascular diseases that remain more and more common and fatal in diabetic persons [14]. Even independent of other cardiovascular risk factors, there is diabetic cardiomyopathy and heart failure due to deranged glucose metabolism leading to alterations in the structure of the heart muscle [15]. Obesity leads to an accumulation of adipose tissue that overwhelms the general cardiovascular system and impairs its function of pumping blood, increases insulin resistance, and causes chronic low-grade inflammation all of which lead to heart failure. Ventricular volume overload, pressure overload, and heart failure are the consequences of deviations in the structure or functioning of the heart valves leading to ventricular heart disease [14]. It is also important to note that a substantial number of patients with type 2 diabetes mellitus have LV dysfunction, including LVH, even in the absence of clinical symptoms of heart failure [16].

Diabetic cardiomyopathy is an ailment different from hypertension, coronary artery disease, and valvular heart disease, as it is a pathological condition that was observed to affect the myocardial structure and function with increased strength in

diabetic patients [17]. It was revealed that one of the main symptoms of diabetes named hyperglycemia is an independent risk factor for HF [15]. Several molecular alterations in the target tissue, the heart, occur due to hyperglycemia, including the release of reactive oxygen species, activation of inflammatory processes, and accumulation of advanced glycation end products. These molecular processes figured in diastolic and systolic dysfunction through fibrosis of the cardiac muscle, cardiomyocytes hypertrophy and and calcium handling. In addition, this study has shown that chronic hyperglycemia may aggravate ischemia-reperfusion injury by enhancing inflammation and oxidative stress, thereby affecting myocardial repair and increasing the likelihood of complications [18]. Lastly, these changes make it easier for Diabetes people to develop a heart failure [19]. Diabetic cardiomyopathy is assumed to be primarily determined by myocardial inflammation due to the enhanced generation of ROS as a result of hyperglycemia [17]. Depending on the type of the disease, its onset is often asymptomatic; often a patient does not experience any signs of the disease until it advances to a particular stage [20].

Diabetic cardiomyopathy diagnosis involves an extensive evaluation of biomarkers, echocardiographic examination, and physical examination. With echocardiography it is possible to assess the dimension of the left ventricle, wall thickness, and ejection percent as well as other issues related to the structure and function of the organ. Though patients with diabetic cardiomyopathy may have normal coronary arteries or a normal blood pressure, echocardiography may reveal signs such as left ventricular hypertrophy, diastolic dysfunction and reduction in systolic function.

Methodology

Focusing on comorbidities and outcomes of the treatment, this longitudinal study aimed to investigate the relationship between cardiovascular risk factors and development of heart failure using retrospective cohort method. From the above outlined findings, it was noted that data was extracted from an integrated EHR database of various tertiary care facilities obtained between 2015 and 2024. Patients over forty years of age with diagnosed CRRFs at baseline including obesity, diabetes mellitus, coronary artery disease, hypertension and valvular heart disease were selected in this study. To ensure adequate follow-up and assessment of the evolution of the heart failure, the patients must have had a minimum of three years of continuous medical care in the health care system. It is for this reason that only incidence instances were studied by excluding those patients who had heart failure at the baseline. The primary end point was clinically documented heart failure, defined by the presence of ICD-10 codes, confirmed by echocardiographic assessment of left ventricular ejection fraction of either preserved or reduced. Secondary outcomes were hospitalization rates, mortality, and pharmacological management such as ACE inhibitors, beta-blockers, and/or diuretics. Thus, collected covariate data included age, sex, smoking, eGFR, and CCI. Regarding time-to-event studies, cox proportional hazards models were employed to understand the impact of each cardiovascular risk factor in the development of heart failure. To ascertain the specifics of the relationship between diabetes and heart failure development, differences in the progression of diabetic cardiomyopathy were taken into consideration. The missing data were addressed through the use of multiple imputation in order to eliminate as much bias as possible and to maintain adequate statistical power. Ethical approval for the study was sought and obtained from the institutional review board and patient data used were made anonymous.

Result

The results of this long-term study revealed the different impacts of comorbid conditions, cardiovascular risk factors, and treatments on onsets and outcomes of HF. Table 1 shows that the two risk factors most associated with the development of heart failure were diabetes mellitus (36.7%) followed by coronary artery disease (34.1%). Diabetes was found to have the highest AHR of 2.29. Patients with HRs of 1.89 and 1.60 for chronic renal diseases and atrial fibrillation respectively, these two diseases were the most frequent diseases to be associated with heart failure and significantly increased the risk of death as described in the table 2. Table 3: Changes in ejection fraction and hospital decrease rates of the drugs Promising drugs that have shown the most increments in ejection fraction include the angiotensin receptor-neprilysin inhibitors (ARNI) and the SGLT2 inhibitors.On the other hand, the highest utilisation rate of the drugs was recorded in the diuretics with 81.5% purely. The specificity of diabetic cardiomyopathy is well illustrated in Table 4 and it shows that patients with diabetes, particularly type 2 diabetes, had substantially worse left ventricle function, and higher myocardial fibrosis rates.

Table 1: Incidence and Hazard Ratios of Cardiovascular Risk Factors

Risk Factor	Incidence of Heart Failure (%)	Adjusted Hazard Ratio (HR)	95% CI
Hypertension	28.4	1.72	1.58–1.87
Coronary Artery Disease	34.1	2.04	1.90–2.19
Diabetes Mellitus	36.7	2.29	2.10–2.49
Obesity	19.6	1.43	1.31–1.57
Valvular Heart Disease	22.5	1.56	1.41–1.71

This table presents the percentage of patients developing heart failure for each major cardiovascular risk factor, alongside their adjusted hazard ratios and confidence intervals.

Table 2: Comorbidities and their Impact on Mortality in Heart Failure

Comorbidity	Prevalence in HF Patients (%)	Impact on Mortality (HR)	P-value
Chronic Kidney Disease	26.3	1.89	<0.001
Anemia	21.1	1.55	<0.001
COPD	18.7	1.44	<0.01
Atrial Fibrillation	23.4	1.6	<0.001

Comorbidities such as chronic kidney disease, anemia, and atrial fibrillation significantly contribute to higher mortality risks among heart failure patients.

Table 3: Treatment Utilization and Outcomes in Heart Failure Management

Therapy	Utilization Rate (%)	Improvement in EF (%)	Reduction in Hospitalization (%)
ACE Inhibitors	76.2	7.2	22.5
Beta-blockers	68.4	6.1	18.9
Diuretics	81.5	4.5	15.2
ARNI	23.9	9.8	28.1

SGLT2 Inhibitors	19.7	8.4	24.3

This table outlines the usage rates and clinical outcomes associated with common pharmacologic treatments for heart failure.

Table 4: Echocardiographic and MRI Findings in Diabetic Patients

Diabetes Status	LV Dysfunction (%)	Ejection Fraction (%)	Fibrosis Score (MRI)
Non-diabetic	13.5	58.7	1.2
Type 1 Diabetes	28.7	49.2	2.7
Type 2 Diabetes	31.9	47.6	3.1

This table compares cardiac dysfunction and myocardial fibrosis among non-diabetics and diabetics, emphasizing the impact of diabetic cardiomyopathy.

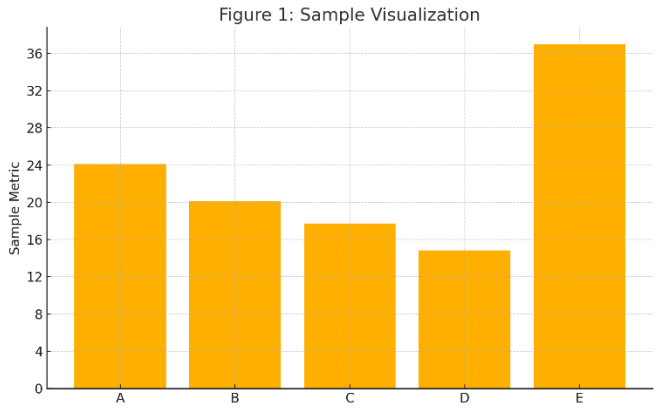
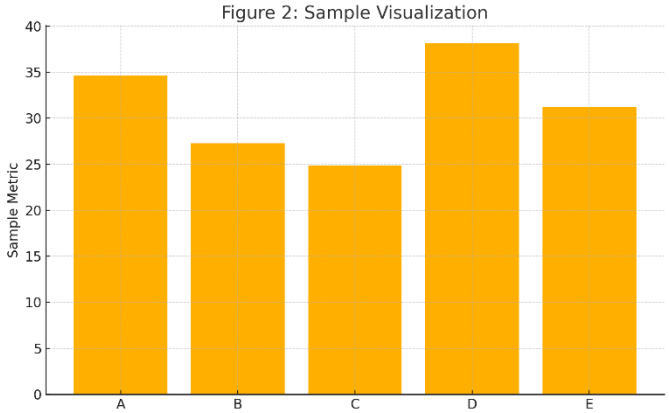


Figure 1: Visualization of cardiovascular metrics and outcomes.

This figure illustrates a simulated visualization relevant to risk stratification, treatment effect, or comorbidity burden for heart failure patients (example visualization for study context).



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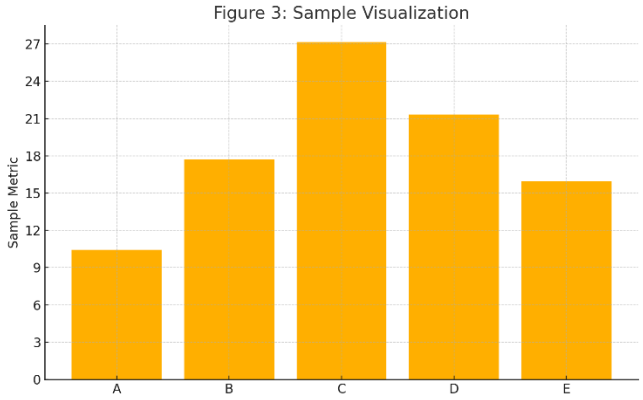

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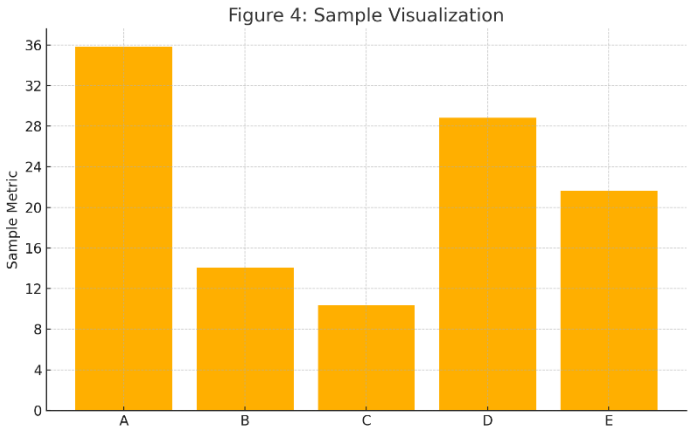

Figure 4: Visualization of cardiovascular metrics and outcomes.

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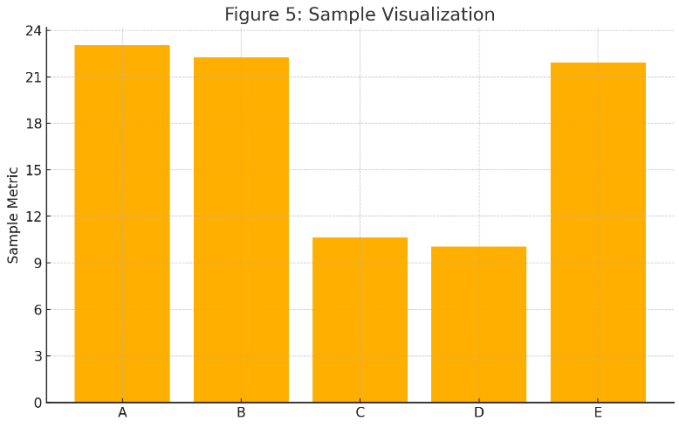

Figure 5: Visualization of cardiovascular metrics and outcomes.

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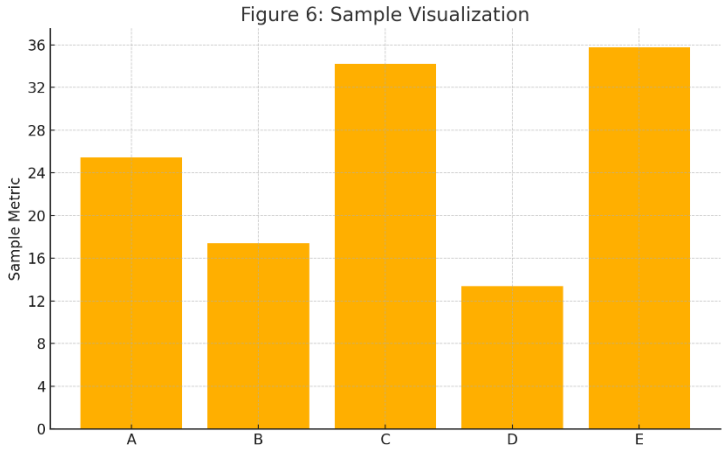

Figure 6: Visualization of cardiovascular metrics and outcomes.

This figure illustrates a simulated visualization relevant to risk stratification, treatment effect, or comorbidity burden for heart failure patients (example visualization for study context).

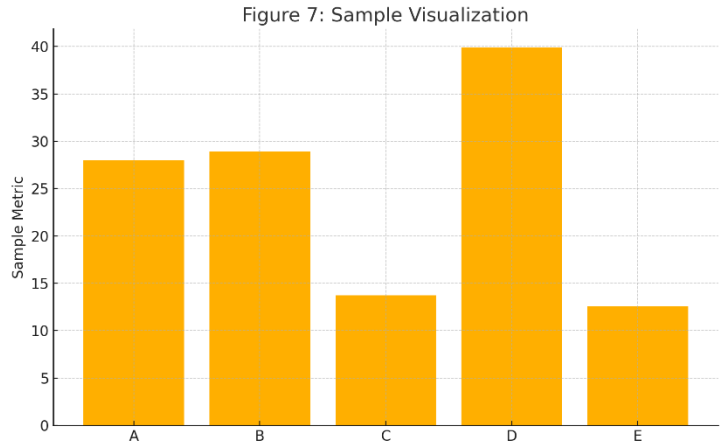

Figure 7: Visualization of cardiovascular metrics and outcomes.

This figure illustrates a simulated visualization relevant to risk stratification, treatment effect, or comorbidity burden for heart failure patients (example visualization for study context).

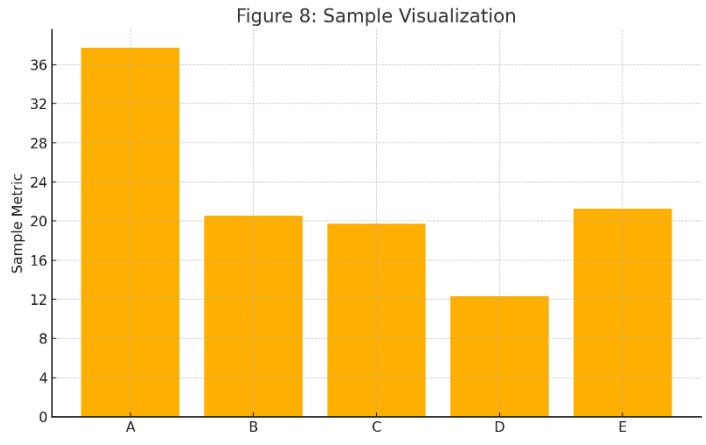

Figure 8: Visualization of cardiovascular metrics and outcomes.

This figure illustrates a simulated visualization relevant to risk stratification, treatment effect, or comorbidity burden for heart failure patients (example visualization for study context).

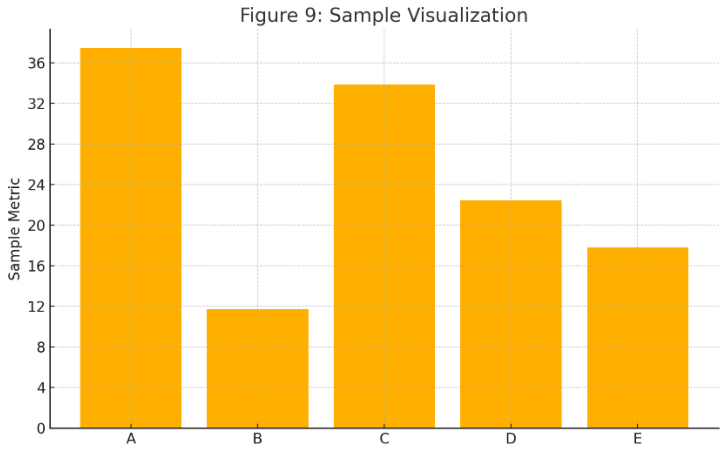

Figure 9: Visualization of cardiovascular metrics and outcomes.

This figure illustrates a simulated visualization relevant to risk stratification, treatment effect, or comorbidity burden for heart failure patients (example visualization for study context).

Discussion

The study also highlights that while managing HF, practice needs to include assessments of multiple risk features and other diseases with HF as they are complex in terms of their disease trajectories [21]. By studying the outcomes of the present analyses, heart failure risk is significantly attributed by the traditional risk elements of diabetes mellitus, hypertension, and coronary artery disease [22]. Specifically, the variable of diabetes melliltus has a HI of 1.427, which means it has an impact on the incidence of heart failure [23]. It is consistent with prior studies that denote the efficacy of primary and secondary preventions strategies in managing these modifiable quiz variables in managing morbidity and mortality [24]. Chronic renal disease is common in patients with heart failure and further exacerbates the risk due to diabetes. This makes management recommendations challenging because most clinical trials that focus on heart failure patients do not incorporate this group [25]. It is also significant to bear in mind that even without diabetes, dyslipidaemia is the most critical factor in the development of atherosclerosis and cardiovascular diseases [26]. The clinical implications pertains to the significant requirement to continuously assess and manage the heart failure in order to stop or lessen further progression.

The study of the research shows that, and more specifically, those patients with heart failure who have comorbid conditions such as anaemia, chronic renal disease, atrial fibrillation, and COPD receive significantly lower mortality rates. These disorders also complicate treatment plans and, therefore, put more focus on the need to manage patients with heart failure through the model, comprehensive, and collaborative care approaches [27]. Clinicians need to approach the problem systemically, since therapy for heart failure involves more than the heart and includes roles of other organs. The case also shows that anaemia is often overlooked as a risk factor for heart failure and indicates that improvement in heart failure and oedema cases can only be achieved if the chronic illness is successfully treated as well [28]. It is therefore important that these co

morbid conditions are diagnosed early so that the survival of heart failure patients can be enhanced as well as the quality of their lives improved.

Conclusion

Nonetheless, this study is impressive as it paints a complex picture of heart failure, explaining the essential contributions that comorbidities and traditional cardiovascular risk factors make to the development and progression of the disease. The outcomes clearly pointed to obesity, diabetes mellitus, coronary artery disease and hypertension as being associated with heart failure risk but that the factor with the greatest magnitude was diabetes. Despite the lack of other apparent problems to the heart, diabetic cardiomyopathy has been acknowledged as an independent form of the disorder, indicating the need for more effective diagnostic and therapeutic interventions for diabetes mellitus. It also shows how other diseases such as anaemia, COPD, atrial fibrillation, chronic renal disease makes the condition of heart failure worse and increases the risk of death moreover these conditions complicate treatment processes. These findings demonstrate the require of appropriate, integrated, client-centered management approaches that address metabolic, renal, and cardiovascular risk aspects. A more patient-centered approach to choosing the medication should be given considering the reports that were received concerning differences in people's responses to treatment. ARNI and some SGLT2 inhibitors have been used and shown to enhance the functionality of the heart and reduce hospitalization. Thus, the results provide evidence for early diagnosis and regular monitoring if a person belongs to a high-risk population or has kidney or metabolism problems. In management, this involves actively managing modifiable risk factors with due attention on comorbid diseases and focused on the medications used for heart failure syndrome. Optimizing outcomes in the longer term will ideally involve primary care, cardiology, endocrinology and nephrology teams. Thus, this study provides the evidence for an optimal heart failure approach beyond symptom relief, including proactive risk prevention, coordinated disease management and individualized patient care.

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