

A Peer Review of a Predictive Model for Early Detection of Heart Failure Using Machine Learning

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Abstract: Most heart failure is detected in designated health facilities using either biomarkers or the client's history by healthcare specialists. These setbacks are attributable to the client's willingness to visit the facility regularly for checkups to determine if any relatives have experienced heart failure or have had any predisposed conditions. This paper systematically reviewed different algorithms employed in early detection of heart failure using artificial intelligence based on attributes like age, blood pressure, family history, diabetes, biomarkers, and angina. Thus, the review provided information about existing models for early detection of heart failure, including their strengths and weaknesses. It was observed that patients' survival stages of flow of pain before and during spark heart failure; the fluid lipid membrane filtered the stress fluid from the atriums and ventricles and accumulated in the left lower pericardial heart failure and the accurate proportionate lipid (kg/dL) in the blood required for aerobic respiration. It is observed in the review that although a significant research effort has been made on heart failure detection, a thorough literature review is still slugging and concluded that detecting heart failure in hospitals without inculcating turn-around costs, distance, disability status, proximity to healthcare, treatment level, home, orthodox diagnosis and treatment, and other treatment centers. Hence, the fusion of these attributes will help improve early detection of heart failure. Early identification of heart disease is critical because it is one of the primary causes of cardiovascular disease-related deaths worldwide. Biomarkers, biomedical care, healthcare, and disease prediction are now actively using emerging technologies like machine learning and deep learning. This research compares and analyses current prediction models with an emphasis on heart failure prediction. Metrics like accuracy, recall, and ROC curves assess supervised machine learning for prediction algorithms like K-Nearest Neighbors, Binary Logistic Classification, and Naïve Bayes. The effectiveness of these foundation classifiers was evaluated against ensemble modeling strategies including stacking, boosting, and bagging.

Keywords: Heart failure, Dyspnea, Congestion, Detection, Biomarkers, Turn-around cost.

1. Introduction

The use of machine learning in the early identification of heart failure (HF) is a data-driven, practical approach to lowering the prevalence of this ancient, debilitating illness that affects families, nations, and states. Since early detection results in preliminary therapy, artificial intelligence (AI) is the way

forward for the prompt detection of these types and classes of diseases. The Savarese and America Heart Association (2022) estimates that heart failure directly affects over sixty-four million people globally. This clinic syndrome contributes to hospitalization in the elderly with 5 to 10 hospital admissions. The application of data and algorithms to simulate the processes of making optimal, efficient, effective, and accurate decisions in a world of scarcity is the emphasis of machine learning (ML), a subfield of artificial intelligence with a touch of computer science (IBM).

Congestive heart failure occurs when the heart does not sufficiently oxygenate to and deoxygenated the organs in the body through the veins and arteries with insufficient or not at all. It may gradually develop in any of the chambers when the heart is damaged it is attributable to ageing and lifestyle. The sudden development of heart failure (the Acute) is eruptive, and its randomness prepares and readiness to difficult to predict. The heart has two chambers which are the right and the left chambers, the causes of medical condition that can damage the heart include inflammation, high blood pressure, cardiomyopathy, and coronary heart disease.

Heart failure may lead to damage of liver and kidney malfunctioning resulting in conditions such as irregular heartbeat, pulmonary hypertension, valve disease, and cardiac arrest. A physician will diagnose client as a heart failure client based on the medical and family history, physical exam, and results from imaging and blood test. Currently, chronic diseases such as heart failure have no cure treatment such as healthy lifestyle changes, medicines. Blood tests check the levels of certain molecules, such as brain natriuretic peptide (BNP), echocardiography (Echo) which measures the ejection fraction. Ejection fraction is the percentage of blood in the lower left chamber (the left ventricle) is responsible for pumping out with each heartbeat and these are categories as if.

- i. Forty percent or less of blood in the left ventricle pumped out in a beat, then you have heart failure reduced ejection fraction.
- ii. Fifty percent or more of blood in left ventricle pumped out in a beat, which considered heart failure preserved ejection fraction and,

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- iii. Forty-one percent to 49% of the blood in the left ventricle, which is considered heart failure with borderline ejection fraction.

Imaging tests can show how well your heart pumps blood at each heartbeat, such as cardiac magnetic resonance imaging (MRI) and computer tomography (CT) scan or nuclear heart scan. Cardiac catheterization with coronary angiography, also used to scan the arteries in the heart for blockers. The heart electrical activity that checked through electrocardiogram (EKG) or a Holter/event monitor which you wear for a day to two days or more whiles executing your daily activities. A stress test measures how well the heartbeat is during exercising.

The stages through which physicians' diagnosis heart failure are cumbersome, it was required by the specialist to exhaustively digest client's history. Then, the client is interrogated if experiencing cough, general fatigue, dyspnea, nocturia, and other signs and symptoms of heart failure. Dyspnea is a root symptom of failing heart and with time it develops to orthopnea, dyspnea on rest and paroxysmal nocturnal dyspnea (cough). The progression of heart fatigue leads to gastrointestinal symptoms like abdominal bloating, anorexia, and fullness in the right quadrant.

A client complained of chest pain or myocardial infarction because of coronary artery disease which is 75% of cases of heart failure with declining left ventricular functionality. With established myocardial infarction is strongly bind of sensitivity, specificity, and positive and negative value result for heart failure with diabetes, blood pressure, etc. Blood pressure, valvular heart disease (aortic and mitral disease), pericardial disease, drug intake and abuse (cyclophamide/Cytosan, cocaine, wee, aphrodisiacs, doxorubicin/Adriamycin), alcohol, infiltrative disease (like amyloidosis, sarcoidosis, hemochromatosis, and malignancy), radiation exposure and endomyocardial disease by New York Heart Association (NYHA) 2023.

2. Materials

A. Structure Examination.

The second procedure is structure/physical diagnosis of client by the specialist if client exhibits signs and symptoms of heart failure. The general structure was assessed for resting dyspnea, cachexia, and cyanosis present.

B. Classification of Heart Failure

Globally deaths attributed to heart failure in 2020 is about 19.1 million and the age-adjusted death rate per 100,000 population was 239.8 with prevalence rate of 7354.1 per 100,000 population in the world (American Heart Association, 2022). Heart failure occurs when the heart is not pumping sufficient and adequate blood in each period whilst congestive heart failure (CHF) is a type of heart failure which demands timely medical attention on any given day. The heart serves as a pressure pump muscular valve that does the distribution of oxygenated blood from the lungs through the left atrium into left ventricle (LV) with simultaneous deoxygenation from the right atrium into the right ventricle (RV) to the lungs.

Heart failure is basically in three main dimensions, these are the left ventricle ejection fraction (LVEF), heart failure with reduced ejection fraction (HrEF) is divided into two types and the first one is Systolic heart failure and is defined as LVpEF less or equal to 40 percent, and the second one is diastolic heart failure is greater than or equal to 50 percent. The second type of heart failure is right sized here failure and the last is congestive heart failure. Heart failure with an average ejection proportion is between these standardized values (Savarese G. and Lund L. H., 2017, Lam C. S. P., and Solomon S. D., 2021) (NYHA) functional classification as follows:

Class I: Normal physical activity does not result in symptoms from heart failure, nor does it limit physical activity.

Class II: Patients are comfortable at rest but experience mild limits in their ability to exercise; regular physical exertion triggers heart failure symptoms.

Class III: Patients with heart failure have significant limitations to their physical activity; they feel comfortable at rest, but their symptoms worsen with less than usual exertion.

Class IV: Heart failure patients experience symptoms while at rest or are unable to engage in any physical activity without experiencing heart failure symptoms.

The four stages that comprise the American College of Cardiology/American Heart Association (ACC/AHA) staging scheme are as follows:

Stage A: Elevated risk of cardiac arrest without any structural

Stage B: Refractory heart failure necessitating specialist interventions.

Stage C: Structural heart disease and symptoms of heart failure.

Stage D: Structural heart disease and no symptoms of heart failure.

1) Laboratory Detection of Heart Failure

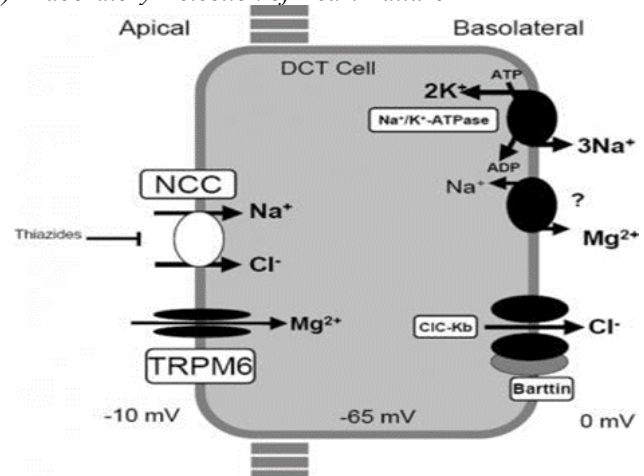


Fig. 1. Laboratory detection of heart failure using electrolyte levels

Clients with heart failure experience normal electrolyte levels. The excessive use of kaliuretic diuretic normally leads to low potassium in the bloodstream (hyperkalemia), blood urea nitrogen and creatinine levels may become elevated and may be present clients with developed HF. When the serum potassium level is less than 3.5 mEq/L (3.5 mmol/L), it is referred to as hypokalemia. Serum levels between 2.5 and 3.0 mEq/L are

considered moderate hypokalemia, while those below 2.5 mEq/L are considered severe hypokalemia. One potentially fatal imbalance that can be brought on by medication errors is hypokalemia.

From figure 1, an illustration of the distal convoluted tubule's transport systems. Sodium chloride (NaCl) passes through the basolateral Cl^- channel (ClC-Kb), the Na^+/K^+ -ATPase, and the apical thiazide-sensitive NCC to exit the cell. Additionally indicated are a potential Na/Mg exchange in the basolateral membrane and the recently discovered magnesium channel TRPM6 in the apical membrane. Gitelman syndrome, also known as familial hypokalemia-hypomagnesemia, is influenced by these transport systems by Lederer, 2023.

Electrocardiography (ECG) is required for clients with possibility of heart failure, the atrial and ventricular arrhythmias are common in elderly clients with advancement of heart failure by Murrler et al, 1991.

Lipids are fatty waxlike molecules found in the human body and there are several roles of lipid in the body important in many ways and some specific ways are, it serves as solvent in dissolving vitamins in fat, a source of energy for daily diet, sending signals through the body, and in the structure of cell membranes and storage of tissues as a reserve energy. Lipids are measured in milligram per deciliter of blood (McCarthy 2014).

2) Diagnosing Client of Heart Failure.

The final stage of diagnosing a client of heart failure is rarely heart broken. This means that all relevant history, scans, and tests were conducted, and the specialist is convinced, then, the client is psych on heart failure by sensitizing him/her on measures of treating the disease and things to avoid lifelong. In addition to traditional approaches, there are several decision support systems that employ computational methods for the detection of cardiac disease, including machine learning, fuzzy logic, artificial neural networks (ANN), and neuro fuzzy.

In today's world, computer technology is used extensively in all fields, including medicine diagnosis. Strong logical thinking skills, experience, and the application of suitable techniques are all principal factors in making diagnostic choices. considering this industry, which uses highly sophisticated and disorganized computers.

Fuzzy logic is a strong reasoning technique that excels at managing data ambiguity, which is why expert systems like this are employed. The practical applications of fuzzy systems in medicine, control, and other fields are growing in number [3] and [16].

3) Drugs Prescription for Heart Failure Client

The notion of no cure and all that it requires is managing by lifestyle change, exercising and regular intake of prescribed drugs by the specialist. Prescription of drugs, dosage and intake vary from physician to physician. The general factors considered before prescribing drugs for client are age, body mass, height and weight, existing medical conditions, drug interactions and medical intolerance according to Majid et al, 2024.

The routine for diagnosing heart failure is centered within hospital and laboratory. The final decision based on scans and

laboratory tests conducted and duly submitted to the specialist with prior information from client's history are used to diagnose the category and degree of heart failure. Clients must keep these essential scans and imaging for any other day of revisitation or readmission to prevent duplication of scans and imaging. Computed tomography (CT) has altered the way physician practice medicine due to it faster, and more accurate diagnostic information with less invasiveness than ever before and advantageous to clients (Liguori et al, 2015). ("Organ doses, effective dose, and cancer risk estimation from head and neck Computer Tomography scans").

Heart failure stochastic diagram

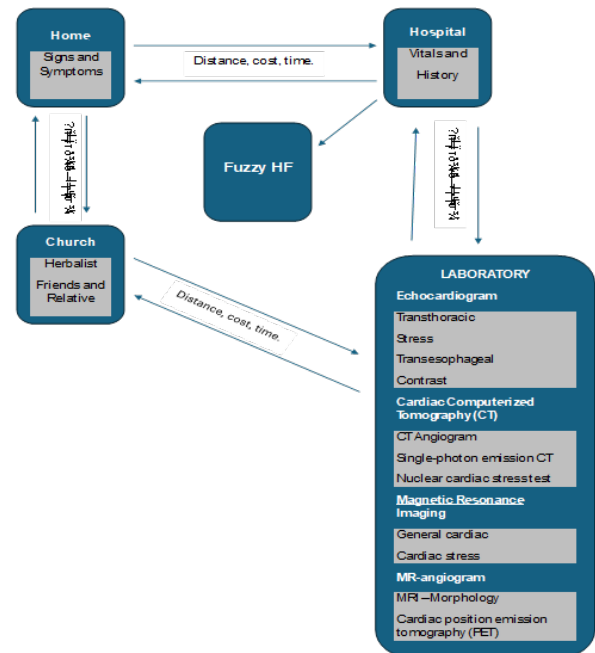


Fig. 2. Heart failure stochastic diagram showing the path of exposed clients

From figure 2, depicts the situation where clients are exposed to multiple computer tomography scan is a basic underlying principle of radiation of radiation protection which is critical according to Kwee et al., 2020) and radiation doses differ exceptionally amongst hospital, clients, and nations (Smith-Bindman et al., 2019; Sulieman et al., 2020).

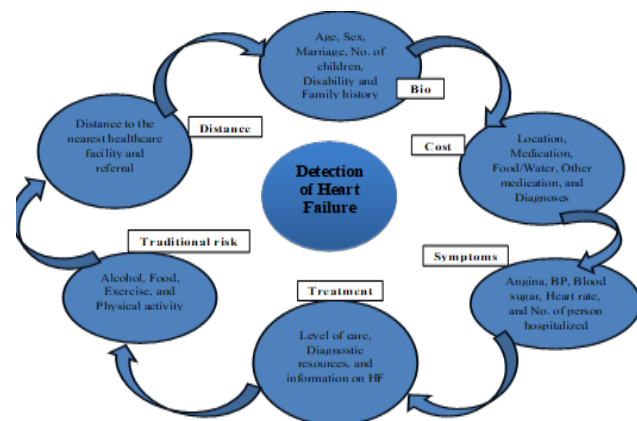


Fig. 3. Flow chart of features

From figure 3, the individual may or not exhibit signs and symptoms for onward action. The patient might visit other sources or the hospital for medical care, this process may be cumbersome in nature. Patients may also access information online, friends, relatives, tele-healthcare, and websites without necessarily a scientific diagnostic.

4) *Heart Failure Treatment*

According to Erksso 1995, there is the need for early recognition and adequate and timely treatment of heart failure. Adequate and timely treatment is a sure strategic economic benefit as far as the individual, public health is concerned and the economy. However, early detection of heart failure will enable the population to leave long by reducing incidents attributable to heart failure even though self-management model has contributed to reduce in client's hospitalization and improved quality of life, more is needed. The expensive newer drugs with unavoidable cost of hospitalization and incident of myocardiatic events. Data-driven of enalapril by the SOLVD Investigators in 1991 and 1992, the Consensus 1987 and Cohn 1991 exhibited that not only relieve symptoms and retard the progression of heart failure prolong survival and reduce morbidity.

5) *Burden of Cardiovascular Diseases in Ghana*

The WHO has identified cardiovascular diseases as one of the top two causes of death in Ghana, after diarrheal illnesses. In 2008, cardiovascular diseases were the most prevalent contributor to mortality in Ghana among all national cardiovascular diseases as well as the leading cause of institutional deaths, accounting for 14.5% of reported total deaths in the country compared to 13.4% of deaths from malaria. The World Health Organization (WHO) estimates that for Ghana, the probability in percentage point of dying from cardiovascular disease, cancer, diabetes, or chronic respiratory disease between ages 30 and 70 is 20 percent. In Ghana's capital, Accra, cardiovascular diseases rose from being the seventh and tenth cause of death in 1953 and 1966 respectively, to becoming the leading cause of death in 1991 and 2001. Even for a peri-urban district in the eastern region of Ghana, cardiovascular diseases ranked as the leading cause of death in 2014. A study in Kumasi, Ghana's second-largest city, identified 17.9% of acute medical admissions as attributable to cardiovascular disease causes including heart failure and stroke. In 2011, stroke and cardiovascular disease ranked as the 3rd and 5th leading causes, of death in Ghana, accounting for 7.34% and 6.97% of all deaths, respectively.

In Ghana, the burden of hypertension is on the upward trend. Between 1988 and 2007, the number of reported new cases of hypertension in the country's outpatient public health facilities increased by more than 1,000 percent. The estimated prevalence of hypertension is high, at 36.4%. A systematic review also identified the prevalence of hypertension in Ghana to range from 19.3% in rural areas to 54.6% in urban areas. Nonetheless, a sizeable portion of Ghana's hypertensive population is still undiagnosed. In a recent study in three urban communities, for instance, only 7.4% of people with high blood pressure were aware. Even among the hypertensive population in Ghana, Blood Pressure control remains terribly low, at less

than 5%. Diabetes is also on the rise in Ghana. The current estimate of the prevalence of diabetes in Ghana is around 6%, with about 450,000 cases of the disease in the country in 2014.

The medical expenditure in household costing was higher amongst household with cardiovascular diseases in Ghana and South Africa where households with cardiovascular diseases living in Ghana are likely to spend twice 5% more than the thresholds of 1.946 odds ratio, with households above 10% health expenditure quadruple for both 25% and 40% thresholds of 3.696 and 4.107 odds ratios respectively (Folashayo et al, 2023).

6) *Cost of Scans and Test Leading to Heart Failure Detection*

The turn-around-cost of health care burden on patients with heart failure continuously increasing even with the introduction of Health Insurance Scheme (HIS) and with inflation of 41.9% in March 2023 and Producer Price Index (CPI) by Ghana Statistics Service (2023) which implies that a patient with cardiovascular diseases may spend more in terms of transportation, food, water, and drugs.

- 1) *The cost of electrocardiogram (EKG)*: is between USD\$54 to USD\$219 (GH¢ 810 to GH¢ 3,285 in Ghana where one United States Dollar is equivalent to GH¢ 15.00 as of May 2024). For a state-owned hospital, according to Ofori et al, 2021.
- 2) *Magnetic Resonance imaging (MRI)*: examinations cost between GHC 702.3–895 (US\$ 121.8–155.3), whereas privately-owned Magnetic Resonance imaging equipment cost between GHC 829.8–1113.3 (US\$ 143.9–191.1). Magnetic Resonance imaging treatments are too expensive given that the average monthly income of Ghanaians is GHC 2200 (US\$ 381.6).
- 3) *Computer tomography (CT) scan*: is a noninvasive and painless diagnostic test used to picturing the structure of clients. This service ranges from GHC 4,500 – 101,250.00 (US\$ 300 – 6,750.00) which depends on the factors like the number of clients in queue, the demand on it, etc. by DeShena, 2023.
- 4) *Chest radiogram*: on average it will cost a client GHC 795.00 (US\$ 80.00), which is subject to health insurance and the facility where the service is rendered. In Ghana, the clients bear the full cost of this service either in the Government hospitals or private hospitals or the laboratories.
- 5) *Cardiac catheterization and Blood test*: it is estimated that cardiac catheterization with or without coronary angiogram costs about client GHC 1,200.00 (US\$ 53.00) Blood test.
- 6) *Holter monitor*
- 7) *Brain Natriuretic Peptide Test (BNP and NT-proBNP)*: Their medical history, including socio-demographic information and examined. The results of the patients' laboratory tests, chest X-ray, electrocardiography, M-mode, and two-dimensional echocardiography with Doppler and colour flow imaging of the patients examined. The result had shown that, patients between 13 to 97 years with average age of 55 years (with standard deviation of plus or minus 19 years), where females constitute 53% and vice versa of males. The main cardiovascular diseases seen

included: hypertensive heart disease (35.6%; $n = 154$), valvular heart disease (19.7%; $n = 85$), cardiomyopathies (18.5%; $n = 80$), arrhythmias (6.3%; $n = 27$) and coronary artery disease (4.2%; $n = 18$).

7) *Cost Burden of Biomarkers*

The cost burden of biomarkers borne by individuals prior to the detection of heart failure in recent times has varied cost from one laboratory to the next. For the detection of heart failure, individuals are subjected to these variant tests, which are blood tests (BT), chest X-rays, electrocardiogram (EKG or ECG), echocardiography (Echo), exercise stress test, cardiac catheterization (CC), magnetic resonance imaging (MRI), and radionuclide ventriculography (RV). The cost of these biomarkers varies from facility to facility. Practitioners often base their judgements on scans and laboratory tests from reliable sources, which are subject to change over time.

The national insurance scheme was instituted to reduce the healthcare burden on the citizenry to enable increased routine checkups for health life, and eventually increase productivity, according to the National Health Insurance Authority (NHIA). According to NHIS, the mission is to provide financial risk protection against the cost of quality basic health care for all residents. It was anticipated that the scheme would reduce the cost of the healthcare services they receive at the facility, which would have a direct impact on their wallets. The scheme was structured to cater for minor services like Outpatients Department charges.

8) *Home Care Services*

There is demand for Health-Related Quality of Care (HRQoC) in homes in Ghana and beyond, as the demand is high for home care nurses and doctors, there is also the need for specialists else well. This trickles up the charge leading to excessive cost of hiring and maintenance of specialists of heart related diseases. According to Williams et al, 2024, reported that there is a downwards slope between the HRQoC and informal caregivers of older adults and the burden including socio-economic, cultural, demographic, and healthcare related factors.

9) *Means of Transportation*

In a 2012 study, Silver et al. examined the connection between transportation challenges and the rate of missed appointments at four independent ambulatory care clinics that are managed by the only public hospital in Nassau County, New York. They surveyed 698 low-income, mostly immigrant consumers over the course of eight days in May 2009 to collect data. According to statistical testing, transportation-related issues caused 23.5% of the patients who responded to skip or postpone appointments; of them, 31.6% were attributable to an inadequate and unreliable bus system. Low frequency, sluggish travel, packed cars, and disregard for the posted timetable were among the grievances. However, what was more concerning was that almost 25% of the individuals who answered the survey said they could not afford to transportation costs to healthcare facilities.

A retrospective analysis of Medicare Advantage beneficiaries in California and Medicaid enrollees in New York was done by Powers et al. (2016) to see if it would be financially

feasible to provide Lyft Concierge services. In May and June of 2016, National Med-Trans (the non-emergency medical transportation benefit manager) collected data on 479 appointments. Based on this data, they discovered that average patient waits times for a trip had fallen by 30% and average ride expenses had lowered by 32.4%. A composite patient measure resulted in an 80.8% satisfaction rating. Similar research by Syed et al. (2013) revealed that transportation difficulties might seriously impede patients from accessing essential medical care, particularly for those from low-income and uninsured backgrounds. Another indicated that transportation obstacles are the main cause of women's.

10) *Persons Living with Disability and Heart Failure.*

Disability is a sociological, legal, and medical condition. Heart failure is a disability due to the discomfort of movement and activity. The proportion of people living with disabilities and heart failure is one of the main concerns of this research work. According to Uzochukwu 2023, a people consider himself/herself medically disabled if he or she has a serious medical diagnosis that affects daily life functioning. Heart failure is a debilitating sickness that may affect individuals' abilities to access health care services in real-time with or without assistance.

There are dissimilar categories of disabilities; the WHO categorizes disability into three basic dimensions, and these are.

- 1) Impairment in a person's body structure or mental functioning, including loss of vision, limbs, and memory.
- 2) Participation restrictions in a normal daily activity like obtaining health care and preventive services, active participation in recreational activities, and active work.
- 3) Activity limitations in routine activity such as hearing, seeing, and walking.

It is estimated that about 1.3 billion people (16%) of the global population experience a significant disability today. These people have an equitable right to the apex of attainable standards of health. People living without disabilities, and people with disabilities find inaccessible and unaffordable transportation fifteen times more likely difficult than those without disabilities.

The most common causes of valvular heart disease, cardiomyopathies, and arrhythmias were rheumatic heart disease, dilated cardiomyopathy, and complete heart block, respectively. In conclusion, our study has shown that hypertensive heart disease, rheumatic heart disease, and cardiomyopathies were the main cardiovascular diseases seen in 73.8% of the patients in this study. (Isaac et al, 2018).

11) *Geospatial of Heart Failure Patients*

This thesis intends to critically investigate the distance and time spent from heart failure patients' locations to the health facilities. The Prior to Diagnostic Geographical Location (PDGL) of these patients is important in the early detection of heart failure and its treatment, Easy accessibility to health care services will help in regular visitation for checkups which might lead to early detection prior to individuals willingly unveiling themselves at the nearest facilities. During the past decade, patients have traveled long distances to access health care. Most patients in Ghana travel from their various communities to

cities for quality health care services. Considering the proximity of the availability of quality healthcare services for the citizenry in every faceted state is prime in healthcare (SDG 17).

Access to quality medical care is defined as a human right in the United Nations Universal Declaration of Human Rights (UDHR). “Everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including medical care states Article 25.1 of the UDHR (UN, 1948)”. The fundamental legal principles of Switzerland include provisions pertaining to healthcare accessibility. As stated in Art. 39 paragraph 1. d KVG and Art. 58b para. 1-3 KVV, the Federal Health Insurance Act (KVG) and the Health Insurance Ordinance (KVV) require the cantons to guarantee that the availability of healthcare is sufficient to meet the needs of the populace. This includes providing “patient access to treatment in a reasonable way.

Geographical healthcare specialized information needed for patients maps to identify their unique inquiries for quick response. In a state of proper dissemination of information on facilities, discharging services in cardiovascular diseases with the presence of specialists boosts the patients’ trust in surety.

Decentralization of specialize healthcare center in Ghana will help improve access to quality healthcare and timely care. There is empirical evidence that this process will positively impact healthcare outcomes of those clients treated in these specialized centers (Nemet and Bailey, 2000).

These traditional methods may exaggerate accessibility and produce erroneous social equity assessments. The purpose of this study is to examine how evaluating fairness in transit-based accessibility to healthcare facilities may be erroneous if risk-management actions made by travelers under uncertain travel conditions are ignored according to Lee and Kim, 2023.

12) Effect of Exchange Rate and Inflation on Medication

The definition of exchange rate fluctuation is the exchange rate’s ongoing volatility (Alagidede and Ibrahim, 2017). The sustainability of the exchange rate is critical in managing economic development locally and internationally because the economic pillars hedge the exchange rate in each period, where it determines the stability of the prevailing economic outlook. Importantly, stable sustainability of the exchange rate directly affects households’ disposable incomes and consumption choices, firms’ decision making, and government fiscal and monetary policies, and trade balance.

According to Hadrat et al. (2023), the use of foreign currency as legal tender in hundreds of developed and developing countries, particularly in West African nations, either as a supplement to or in full lieu of local currency is known as currency substitution. Most of the cross-border trade is conducted in stable, widely accepted currencies, such as dollars, and Ghana uses dollars as its common currency.

The inflation rate in Ghana was 23.5% in the month of February 2024, according to the Bank of Ghana (BoG, 2024). Individuals and organizations depend on prevailing inflation rate to determine how much is required to purchase the same quantity of goods to mitigate shortage, reduce black marketing, and price hikes. In

13) Flow Chart of Classified Variables in Early Detection of Heart Failure

The chart below shows the classification of the variables of interest in unsupervised machine learning. Machine learning model is a basic program that can find patterns and help in decision making from a previously unseen dataset. The algorithms that can identify these patterns or make predictions on unseen datasets. Machine learning classified models as supervised or unsupervised learning. The main difference between the two is that a supervised algorithm postulates labelled input and output training data, while an unsupervised model can process raw, unlabeled dataset.

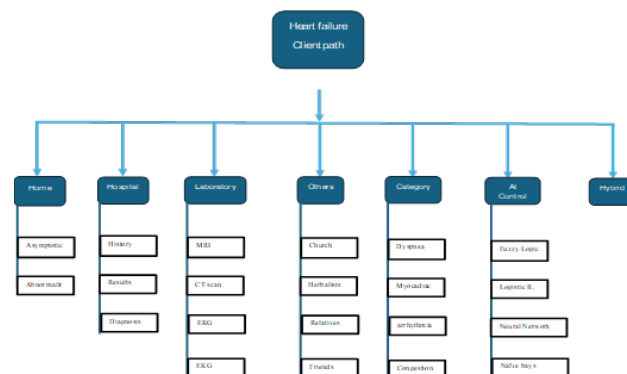


Fig. 4. Likelihood of potential heart failure

Figure 4 depicts the flow chart of features to be analyze using fuzzy logic as employed in supervised machine learning considers the independent variables (x_i) and the response variables (y_i) in modelling to determine the robustness of the model, while unsupervised machine learning does not depend on response variables in deducing meaningful decision from the patterns and classification of salient correlations among variables for onward clustering.

14) Machine Learning Algorithms

The basic supervised learning algorithm includes logistic regression, linear regression, decision trees, support vector machines (SVM), random forests, and neural networks. Unsupervised learning algorithms have no labels, and these techniques are used for clustering, anomaly detection, or dimensional reduction on independent attributes or features. Supervised learning algorithms were employed for this research with emphasis on regression. Heart failure predictive accuracy is 92.31% suggested by Paul et al adaptive weighted fuzzy system ensemble-based model (2017). Ali et al., also suggests a machine learning algorithms by stacking and optimizing two SVMs bind for hybrid of heart failure risk prediction with heart failure prediction performance of 92.22% (2009). according to Samuel et al., (2017) propound an embedded decision support scheme on the ground of artificial neural networks and fuzzy AHP with an output result of 91.10% heart failure risk classification accuracy whilst a model of neural network ensemble proposed by Das et al in improving classification precision and he successfully obtained 89.01 percentage point of prediction accuracy.

The are various datasets pertaining to heart failure with

varying running them thoroughly with machine learning algorithms of notion of achieving dependable performing and accurate predictive model. Data solicited from Cleveland heart disease data used by Mohsin 2023, revealed a logistic regression predictive heart failure risk assessment of classification precision of 77%. The main idea of this research is to improve the precision of heart failure using disability, inflation rate, turn-around-time, turn-around-cost, geo-location, and availability specialist with static features like family history, age, sex and other predispose chronic diseases. The alternative feature like lifestyle is key in curbing heart failure clients.

In concordant with Dr. Hafez Adam Taher (Ghana News Agency, 2023) on the individuals at risk of cardiovascular are usually at the apex of their productive stage in life as there is a rapid change in the demographics from youthful stage group to old age bunchy in high cost of health care are expected to rise as the cost of managing the disease is high, also the Health Service records averagely 200,000 cases of diabetes by health facilities annually. The introduction of Health Insurance Scheme carter for an aspect of general health related issues including cardiovascular diseases, hence, rudimentary healthier problem coronary artery disease of metamorphosis decays erupted abruptly before signs and symptom which is relating to angina and frequent high blood pressure which is often fatal within the youth or active groups. Cerebrovascular with keen acute accent coronary event developed without warning the individual.

15) *Generic Labels and Features of Fuzzy Predictive Model*

Models are developed to mitigate an existing problem or an envisaged problem. Prediction performance was assessed by the mean and standard deviation of the area under the curve (AUC) metrics computed over the cross-validation folds by Kenney et al., 2016. Prediction performance as data types is used in combination starting with demographics/health behaviors and adding vitals, diagnoses, medications, laboratories, hospitalizations, and imaging (Huang et al, 2020).

From most to least common, the combination sequence is determined by our evaluation of each data point's availability. Models that were solely based on vital signs, health-related behaviors, and demographic data did not perform well. The model performs much better when the diagnosis data type is added (AUC 0.733 versus 0.581; $P < 0.00001$). A modest but noteworthy performance improvement is shown upon the addition of the pharmaceutical data type (AUC 0.752 versus 0.733; $P > 0.05$). Notably, the model's performance did not increase with the addition of the laboratory data type. On the other hand, performance was enhanced by the inclusion of the hospitalization data type (AUC 0.791 versus 0.756; $P > 0.001$). Lastly, performance was not improved by the addition of the imaging data types ($p > 0.00001$).

16) *Categories of Machine Learning*

A well-trained machine learning algorithms is the ideal path in data management and modelling of algorithms for predictions and detections in health care. The categories of Machine Learning algorithms are spelt out in table 2.3 in the appendix.

C. Methods and Operational Definitions of Research Variables

The features of this research inculcate features used in diagnosing heart failure as these attributes indicate an appreciable positivity, sensitivity and correlated with the labeled. These are the features subject to existing models are age, family history, exercise angina, blood pressure, blood sugar, and maximum heart rate.

This research would feature these attributes to improve the existing models in determining the degree of incidents of heart failure. Using fuzzy logit, a client with fuzzy logit output of zero indicates absent of heart failure, output greater than zero but less or equal to 25 percent shows a quite moderate heart failure, if the output is greater than 25 percent but less than or equal to 50 percent then it is moderate, a range between greater than 50 percent but less than or equal to 75 percent indicate extreme heart failure and 75 percent plus indicate intensive heart failure which requires intensive treatment through hospitalization and procedures or referral to a specialist if any.

Pivoting our focus from these generic features in other to increasing model predictability and precision, this research infused disability statues, distance to the nearest healthcare, diagnostic resources, source of heart failure information, religious factors, cost of medication, treatment level of care, herbal center, suggestive medication, signs, and hemorrhoid from table 13.1 (Adedayo et al, 2024).

D. Robust Control

Sturdy control techniques are made to manage nonlinearity in the system and model uncertainty. Due to its attractive characteristics regarding external disturbances and model parameter uncertainty, it has been effectively employed to cancel the disturbances in set point tracking.

3. Summary of Findings

It is worth considering that literature reviewed has revealed that research has been done on the globular model for early detection of HF with the fusion of features cost implications, turn-around time, disability status, distance to the nearest healthcare provider, source of information in the model Cardoso A. G., Ahmed S. R., Keshavarz-Motamed Z., et al, 2023). Furthermore, even though hospitals, homes, orthodox and asymptotic clients in early detection model is critical, the various merits and demerits of categories of machine learning algorithms are summarized in the review, their performance in terms of percentage detection, positive and false positivity can surely be improved upon by adapting to robust model that adapt complete features with zero under or overfitting. There are lot of ultimate algorithms in early heart failure detection models, there is more room to explore other recent models to better enhance early detection with varying salient features. Hence, future work will consider the feature model of a novel optimization by other algorithms to better the prompt detection of heart failure incident.

A. Discussion

There are models for predicting heart failure which focus on

biomarkers and clients' history. This article focuses on robust features that will enhance the existing models in heart failure detection models. These features compress labeled and features of cost implications, turn-around time, disability status, distance to the nearest healthcare provider, source of information in the model Cardoso A. G., Ahmed S. R., Keshavarz-Motamed Z., et al, 2023). The health facilities designated with specialist in Ghana are the referral hospitals in Accra and Kumasi with mass clients depending on a health specialist, these clients spend more time in queuing, waiting time, fatigue in revisiting and cost of medical treatment. Clients spend most of early signs of the hatching stages in home and

there is an agent that needs to incorporate these features in model development to increase its reliability and accuracy (Daw, et al. 2021). Furthermore, this will enable early detection of HF and any other related research study.

B. Conclusion

Numerous research has been conducted on early detection of heart failure in recent years. This paper gave an overview of the detection of heart failure process and reviewed current algorithms deployed to address the challenges of accurate and reliable model for early detection. The review shows that no singular globular model is strongly reliable for early, and

Table 1
Merit and Demerit of Machine Learning

S.No.	Category of ML algorithms	Merits	Demerits
Supervised Machine Learning			
1	Regression/decision trees (Ensembles)	It is robust to outliers and performs excellently well with non-linear relationships.	It is easily prone to overfitting due to branching, and it can be solve using Gradient Boosted Tree.
2	K-Nearest Neighbors	It is "instance-based" meaning it save each training observation making prediction on fewer training dataset.	It performs poorly for high-dimensional data and depends on measurable distance function to tabulate similarity with a memory-intensive.
3	Linear Regression	It is simple to model and explain and regularized to avoid overfitting using stochastic gradient descent (adding new dataset).	It performs poorly when there are non-linear relationships and not flexible to capture more complex patterns in data.
4	Logistic Regression	It performs well with non-linear models and can regularized to avoid overfitting using stochastic gradient descent.	It underperforms with non-linear decision boundaries or in multiple decisions.
5	Neural Networks	It performs extremely well with computer speech, imaging, audio, text data and vision recognitions. Easy update with new data using propagation.	It requires exceptionally large data size or sample size and not suitable for inference purposes.
6	Support Vector Machines	It models non-linear decision boundaries with more kernels to select from, its robust against overfitting with high-dimensional spaces.	It is memory intensive and difficult to select the appropriate kernel and averagely scale poorly with large datasets.
7	Naïve Bayes	It heavily depends on conditional probability assumption which performs well. Easy to implement and scale with dataset.	It models become reductants by well-trained models.
Unsupervised Machine Learning (Classifications)			
8	Classification Tree	It is robust to outliers, non-linear decision boundaries and scalable with hierarchical structure.	It is unconstrained and individual trees are volatile to overfitting.
9	K-Means (Geometric distance)	It is flexible and simple with pre-process data and features which allow the researcher to assigned n-clusters	It is difficult to assigned n-clusters and produces poor clusters if the data are not globular.
10	Affinity Propagation (Graph distance between points)	The researcher is not required to specify the n-cluster.	It is quite slow and memory-heavy which makes it difficult to scale with large datasets.
11	Agglomerative/Hierarchical Cluster (Clusters with same ideology)	It scales perfectly with large datasets and does not assume globular.	It is required that the researcher select n-cluster.
12	BDSCan (Density Based algorithm regions)	It does not need every data point to be assigned to a cluster, which reduces the noise of a cluster, it does not assume globular cluster and its performance is scalable.	The researcher must tune the hyperparameters "epsilon" with minimum samples and it is quite sensitive to hyperparameters.
Reinforcement			
13	Markov-Decision Process	It allows machines and software to automatically determine patterns and behavior.	It is required to give a reward as feedback.
14	Quality Learning	It is model-free with a value-based off-policy algorithm that depends on series of actions of current state of the agent.	It requires thoroughly trained datasets with maximum rewards.

Table 2
Existing and suggestive features of Machine Learning

Existing features			
Age	Family history	Sex	Exercise Angina
Fasting blood sugar	obesity	Blood pressure	Cholesterol
Electro	traditional risk factors	Maximum heart rate	Blood pressure
Suggestive features			
Cost of other medication	Cost of food	Disability status	
Exposal to respiratory factors (smoke, etc.)	Distance to the nearest health center	Diagnostic resources	HF information
Treatment level of care	Hemorrhoid	Cost of diagnoses	Signs
Religious factor	Herbal center	Home/family/friend medication	Exchange rate
Cost of medication	Inflation rate		

prediction of HF as labeled. Hence, machine learning algorithms are now gaining popularity in health care management due to their improved detection of diseases in clients and save life, simplicity, adaptability, and robustness. Therefore, future research will propose a novel hybrid detection model for early detection in the medical field to better enhance the existing models in the early detection and treatment (Daw, et al, 2021). There is the need to inculcate these features cost implications, turn-around time, disability status, distance to the nearest healthcare provider, source of information in the model pertaining to the findings.

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The authors affirm that they have no apparent conflicts of interest that would have affected the research presented in this study.

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References

- [1] Savarese G, Becher PM, Lund LH, Seferovic P, Rosano GMC, Coats AJS. Global Burden of Heart failure: a Comprehensive and Updated Review of Epidemiology. *Cardiovascular Research*. 2022 Feb 12;118(17).
- [2] IBM. What Is Machine Learning?. IBM. 2023. Available from: <https://www.ibm.com/topics/machine-learning>
- [3] WHF Roundtable in Ghana: Cardiovascular disease and diabetes on the rise [Internet]. World Heart Federation. Available from: <https://world-heart-federation.org/news/whf-roundtable-in-ghana-2023>
- [4] Home, AHA/ASA Journals. www.ahajournals.org. Available from: <http://ahajournals.org>
- [5] Deserno, M. (2015). Fluid lipid membranes: From differential geometry to curvature stresses. *Chemistry and Physics of Lipids*, 185, 11–45.
- [6] Lam CSP, Solomon SD. Classification of Heart Failure According to Ejection Fraction. *Journal of the American College of Cardiology*. 2021 Jun;77(25):3217–25.
- [7] New York Heart Association (NYHA) functional class [Internet]. www.healio.com. Available from: <https://www.healio.com/cardiology/learn-the-heart/cardiology-review/topic-reviews/new-york-heart-association-nyha-functional-class>
- [8] Lederer E. Hypokalemia: Practice Essentials, Pathophysiology, Etiology. *eMedicine*. 2023 Jun 13; Available from: <https://emedicine.medscape.com/article/242008-overview?form=fpf>
- [9] Paul AK, Shill PC, Rabin MdRI, Murase K. Adaptive weighted fuzzy rule-based system for the risk level assessment of heart disease. *Applied Intelligence*. 2017 Sep 6;48(7):1739–56.
- [10] Feshki MG, Shijani OS. Improving the heart disease diagnosis by evolutionary algorithm of PSO and Feed Forward Neural Network [Internet]. *IEEE Xplore*. 2016. pp. 48–53.
- [11] Liguori N, Xu P, van Stokkum IHM, van Oort B, Lu Y, Karcher D, et al. Different carotenoid conformations have distinct functions in light-harvesting regulation in plants. *Nature Communications*. 2017 Dec 8;8(1).
- [12] McCarthy, K. (2014, June 18). *The Three Classifications of Lipids Found in Food and in the Human Body*. Weekand. <https://www.weekand.com/healthy-living/article/three-classifications-lipids-found-food-human-body-18023436.php>
- [13] Kwee RM, Krdzalic J, Fasen BACM, de Jaegere TMH. CT Scanning in Suspected Stroke or Head Trauma: Is it Worth Going the Extra Mile and Including the Chest to Screen for COVID-19 Infection? *American Journal of Neuroradiology*. 2020 May 21;41(7):1165–9.
- [14] Smith CJW, DiBenedictis BT, Veenema AH. Comparing vasopressin and oxytocin fiber and receptor density patterns in the social behavior neural network: Implications for cross-system signaling. *Frontiers in Neuroendocrinology*. 2019 Apr;53:100737.
- [15] Suleiman-Martos N, Albendin-Garcia L, Gómez-Urquiza JL, Vargas-Román K, Ramirez-Baena L, Ortega-Campos E, et al. Prevalence and Predictors of Burnout in Midwives: A Systematic Review and Meta-Analysis. *International Journal of Environmental Research and Public Health*. 2020;17(2).
- [16] Eriksson S, Xu B, Clayton DA. Efficient Incorporation of Anti-HIV Deoxynucleotides by Recombinant Yeast Mitochondrial DNA Polymerase. *Journal of Biological Chemistry*. 1995 Aug 1; 270(32): 18929–34.
- [17] The SOLVD Investigators. Effect of Enalapril on Survival in Patients with Reduced Left Ventricular Ejection Fractions and Congestive Heart Failure. *New England Journal of Medicine*. 1991 Aug;325(5):293–302.
- [18] Yusuf S, Pitt B, Davis CE, Hood WB, Cohn JN. Effect of enalapril on mortality and the development of heart failure in asymptomatic patients with reduced left ventricular ejection fractions. *The New England Journal of Medicine*. 1992 Sep 3;327(10):685–91.
- [19] Adeniji FIP, Obembe TA. Cardiovascular Disease and Its Implication for Higher Catastrophic Health Expenditures Among Households in Sub-Saharan Africa. *Journal of Health Economics and Outcomes Research*. 2023 Mar 17;10(1).
- [20] September 2023 New Series (2021=100). 2023. Available from: <https://statsghana.gov.gh/gssmain/fileUpload/Price%20Indices/Bulletin%20CPI%20September%202023.pdf>
- [21] Ofori EK, Angmorte SK, Ofori-Manteaw BB, Acheampong F, Aboagye S, Yari C. An audit of MRI machines and services in Ghana. *Radiography*. 2020 Jul;
- [22] How Much Does a CT Scan Cost? - CareCredit. www.carecredit.com. Available from: <https://www.carecredit.com/well-u/health-wellness/how-much-does-ct-scan-cost/>
- [23] World Health Organization. Disability and Health. WHO. World Health Organization: WHO; 2023. Available from: <https://www.who.int/news-room/fact-sheets/detail/disability-and-health>
- [24] SEPTEMBER 2023 New Series (2021=100). 2023. Available from: <https://statsghana.gov.gh/gssmain/fileUpload/Price%20Indices/Bulletin%20CPI%20September%202023.pdf>
- [25] Agyemang-Duah W, Abdullah A, Rosenberg MW. Caregiver burden and health-related quality of life: A study of informal caregivers of older adults in Ghana. *Journal of Health, Population and Nutrition*. 2024 Feb. 21.
- [26] Silver D, Blustein J, Weitzman BC. Transportation to Clinic: Findings from a Pilot Clinic-Based Survey of Low-Income Suburbanites. *Journal of Immigrant and Minority Health*. 2010 Nov 9;14(2):350–5.
- [27] Powers MA, Bardsley J, Cypress M, Duker P, Funnell MM, Fischl AH, et al. Diabetes self-management education and support in type 2 diabetes: A joint position statement of the American Diabetes Association, the American Association of Diabetes Educators, and the Academy of Nutrition and Dietetics. *Clinical Diabetes*. 2016;34(2):70–80.
- [28] Syed ST, Gerber BS, Sharp LK. Traveling Towards Disease: Transportation Barriers to Health Care Access. *Journal of Community Health*. 2014 Dec 13;38(5):976–93.
- [29] Medical News Today. Medical News Today. Medical News Today. 2019. Available from: <https://www.medicalnewstoday.com>

- [30] World Health Organization. Disability and Health. WHO. World Health Organization: WHO; 2023. Available from: <https://www.who.int/news-room/fact-sheets/detail/disability-and-health>
- [31] Owusu IK, Acheamfour-Akokuah E. Pattern of Cardiovascular Diseases as Seen in an Out-Patient Cardiac Clinic in Ghana. *World Journal of Cardiovascular Diseases*. 2018;08(01):70–84.
- [32] Institute RP. 5 Reasons Why Institutional Investors Should Prioritize Underserved Markets. Blog | People, Planet, Sustainability. Available from: <https://readyplayerventures.com/en/blog/5-reasons-why-institutional-investors-should-prioritize-underservedmarkets/>
- [33] United Nations. Universal Declaration of Human Rights [Internet]. United Nations. 1948. Available from: <https://www.un.org/en/about-us/universal-declaration-of-human-rights>
- [34] Nemet GF, Bailey AJ. Distance and health care utilization among the rural elderly. *Social Science & Medicine*. 2000 May 1;50(9):1197–208.
- [35] Lee J, Kim J. Social equity analysis of public transit accessibility to healthcare might be erroneous when travel time uncertainty impacts are overlooked. *Travel Behaviour and Society*. 2023 Jul;32:100588.
- [36] countrymeters.info. World population 2023, Population clock live. Countrymeters.info. 2017. Available from: <https://countrymeters.info/en/World>
- [37] Ogunpola A, Saeed F, Basurra S, Albarrak AM, Qasem SN. Machine Learning-Based Predictive Models for Detection of Cardiovascular Diseases. *Diagnostics* [Internet]. 2024 Jan 1;14(2):144.
- [38] Whelton PK, Carey RM, Aronow WS, Casey DE, Collins KJ, Dennison Himmelfarb C, et al. 2017., ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the Prevention, Detection, Evaluation, and Management of High Blood Pressure in Adults: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Hypertension*. 2018 Jun;71(6).
- [39] Woodard D. How Much Does a CT Scan Cost?. *GoodRx*. 2022. Available from: <https://www.goodrx.com/health-topic/procedures/ct-scan-cost>
- [40] Davari M, Khorasani E, Tigabu BM. Factors Influencing Prescribing Decisions of Physicians: A Review. *Ethiopian journal of health sciences*. 2018;28(6):795–804.
- [41] Medical News Today. Medical News Today. Medical News Today. 2019. Available from: <https://www.medicalnewstoday.com>
- [42] Global report on health equity for persons with disabilities. www.who.int. Available from: <https://www.who.int/teams/noncommunicable-diseases/sensory-functions-disability-and-rehabilitation/global-report-on-health-equity-for-persons-with-disabilities>
- [43] National Institute on Aging. Heart Health and Aging. National Institute on Aging. 2018. Available from: <https://www.nia.nih.gov/health/heart-health/heart-health-and-aging>
- [44] World Health Organization. Cardiovascular diseases (CVDs). World Health Organization. World Health Organization; 2021. Available from: <https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-cvds>
- [45] Hadrat Yusif, Samuel Tawiah Baidoo, Michael Kofi Hanson. Estimating the effect of currency substitution on exchange rate volatility: Evidence from Ghana. *Cogent social sciences*. 2023 Jul 7;9(1).
- [46] Bank of Ghana – Central Bank. Available from: <https://www.bog.gov.gh>
- [47] Samuel OW, Asogbon GM, Sangaiah AK, Fang P, Li G. An integrated decision support system based on ANN and Fuzzy_AHP for heart failure risk prediction. *Expert Systems with Applications*. 2017 Feb;68:163–72.
- [48] Ali L, Rahman A, Khan A, Zhou M, Javeed A, Khan JA. An Automated Diagnostic System for Heart Disease Prediction Based on χ^2 Statistical Model and Optimally Configured Deep Neural Network. *IEEE Access*. 2019;7:34938–45.
- [49] Paul AK, Shill PC, Rabin MdRI, Murase K. Adaptive weighted fuzzy rule-based system for the risk level assessment of heart disease. *Applied Intelligence*. 2017 Sep 6;48(7):1739–56.
- [50] Shiau JJH. A new algorithm for 5-band Toeplitz matrix inversion with application to GCV smoothing spline computation. *Statistics & Probability Letters*. 1999 Dec;45(4):317–24.
- [51] Ng K, Steinhubl SR, deFilippi C, Dey S, Stewart WF. Early Detection of Heart Failure Using Electronic Health Records. *Circulation: Cardiovascular Quality and Outcomes* [Internet]. 2016 Nov [cited 2020 Feb 1];9(6):649–58.
- [52] Kramer BJ, Cote SD, Lee DI, Creekmur B, Saliba D. Barriers and facilitators to implementation of VA home-based primary care on American Indian reservations: a qualitative multi-case study. *Implementation Science*. 2017 Sep 2;12(1).
- [53] Lloyd-Jones D, Adams RJ, Brown TM, Carnethon M, Dai S, De Simone G, et al. Heart disease and stroke statistics--2010 update: a report from the American Heart Association. *Circulation*. 2010;121(7):e46–215.
- [54] Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, Ameh EA, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *The Lancet*. 2015 Aug;386(9993):569–624.
- [55] Chronic Kidney Disease Prognosis Consortium, Matsushita K, van der Velde M, Astor BC, Woodward M, Levey AS, et al. Association of estimated glomerular filtration rate and albuminuria with all-cause and cardiovascular mortality in general population cohorts: a collaborative meta-analysis. *Lancet (London, England)*. 2010;375(9731):2073–81.
- [56] The Consensus Trial Study Group. Effects of Enalapril on Mortality in Severe Congestive Heart Failure. *New England Journal of Medicine*. 1987 Jun 4;316(23):1429–35.
- [57] Cohn JN, Johnson G, Ziesche S, Cobb F, Francis G, Tristani F, et al. A Comparison of Enalapril with Hydralazine–Isosorbide Dinitrate in the Treatment of Chronic Congestive Heart Failure. *New England Journal of Medicine*. 1991 Aug;325(5):303–10.
- [58] Agyemang-Duah W, Abdullah A, Rosenberg MW. Caregiver burden and health-related quality of life: A study of informal caregivers of older adults in Ghana. *Journal of Health, Population and Nutrition* [Internet]. 2024 Feb 21;43(1):31.
- [59] Owusu IK, Acheamfour-Akokuah E. Pattern of Cardiovascular Diseases as Seen in an Out-Patient Cardiac Clinic in Ghana. *World Journal of Cardiovascular Diseases*. 2018;08(01):70–84.
- [60] Mahmud I, Kabir MM, Mridha MF, Alfarhood S, Safran M, Che D. Cardiac Failure Forecasting Based on Clinical Data Using a Lightweight Machine Learning Metamodel. *Diagnostics* [Internet]. 2023 Jan 1;13(15):2540.
- [61] GNA. Ghana risks losing workforce to Cardiovascular Diseases. Ghana News Agency. 2023. Available from: <https://gna.org.gh/2023/03/ghana-risks-losing-workforce-to-cardiovascular-diseases/>
- [62] Ng K, Steinhubl SR, deFilippi C, Dey S, Stewart WF. Early Detection of Heart Failure Using Electronic Health Records. *Circulation: Cardiovascular Quality and Outcomes*. 2016 Nov;9(6):649–58.
- [63] Huang SC, Pareek A, Zamanian R, Banerjee I, Lungren MP. Multimodal fusion with deep neural networks for leveraging CT imaging and electronic health record: a case-study in pulmonary embolism detection. *Scientific Reports*. 2020 Dec 17;10(1):22147.
- [64] Shilpa, T., Harikrishna, P., and Naresh P. V. (2015). Digital Notes on Machine Learning. Malla Reddy College of Engineering & Technology. India. Access, 2024.