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RESEARCH ARTICLE

PREDICTORS OF HEART FAILURE AMONG PATIENTS UNDERGOING MAINTENANCE HEMODIALYSIS THERAPY

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Abstract

This study aimed at identifying predictors of heart failure among patients undergoing maintenance hemodialysis therapy at the Dialysis Center of Abood Military Hospital, a major tertiary referral canter in Aden, Yemen. The study utilized a quantitative research approach with an analytical cross-sectional design. The sample of the study is patients who had experienced MHD (51patients) in the center. Data was collected using patient interview form, Laboratory data (documents), echocardiography and diagnosis of heart failure (outcome variable). SPSS v. 21 was used to analyze data. Based on the analysis of the data, the study found a strong predictive ability for heart failure within the study sample. The overall accuracy is 84.3%. It is found that that patients with hypertension are 14 times more likely to develop heart failure compared to those without hypertension and that that patients with smoking are 11 times more likely to develop heart failure compared to those nonsmokers... the odd ration is (OR = 14.03, 95% CI: 0.73–269.35, p = 0.035). and (OR = 11.53, 95% CI: 0.55–248.18, p = 0.028). respectively. The findings showed that there is indeed a statistically significant predictive ability within the model, but it is driven almost entirely by hypertension and smoking rather than the full suite of socio-demographic and dialysis-related factors.

Keywords: Heart failure; Predictors; Maintenance hemodialysis.

Introduction

Heart failure remains a primary driver of morbidity and mortality for patients on maintenance hemodialysis. The prevalence is commonly higher in MHD than the general population. This complex relationship is often described as a negative spiral where the loss of renal function and the physiological demands of dialysis therapy place extreme stress on the cardiovascular system. This study tries to identify prevalence and predictors of heart failure among patients undergoing maintenance hemodialysis therapy at the Dialysis Center of Abood Military Hospital, a major tertiary referral canter in Aden, Yemen.

Statement of the Problem

Cardiovascular disease remains the leading cause of morbidity and mortality among patients with End-Stage Renal Disease (ESRD) on maintenance hemodialysis (MHD). Among these complications, heart failure (HF) is particularly devastating, affecting approximately 30% to 50% of patients. The presence of heart failure in this population not only severely impairs quality of life but also increases the risk of hospitalization and death by several-fold compared to dialysis patients without cardiac dysfunction. The present of a high burden of traditional risk factors, uremia-specific pathophysiology, and resource-limited healthcare system put Yemeni MHD patients at extreme risk for HF. There is an urgent need to determine the current prevalence of heart failure within the maintenance hemodialysis population and to identify the key predictors that lead to its development. Without identifying these predictors, it is impossible to implement early screening protocols or targeted interventions to reduce the high cardiac mortality rates in this vulnerable group. This study tries to determine the prevalence and predictors of heart failure (HF) in hemodialysis Center of Abood Military Hospital, Aden, Yemen.

Significance of the Study

The importance of the study can be clarified in the fact that it will provide crucial data on the cardiovascular burden among hemodialysis patients. By identifying the specific prevalence of heart failure, it helps nephrologists

and cardiologists understand the scale of the Cardio renal Syndrome within this population. Identifying predictors like anaemia, hyperkalemia, and dialysis duration allows for the development of early warning systems to detect heart failure before it reaches an irreversible stage. Regarding local importance, the city is suffering a scarcity of localized research regarding End-Stage Renal Disease (ESRD) complications in Yemen. This study is particularly significant because: Unique Risk Factors: It evaluates the impact of Qat chewing, a prevalent local habit, on cardiac health in dialysis patients a variable often missing from international literature. Resource Allocation: Findings can guide the Aboud Military Hospital and the Yemeni Ministry of Health in prioritizing resources, such as echocardiography screening and specialized cardiac care, for high-risk dialysis patients. For diagnostic optimization, the study contributes in confirm diagnosis of HF by both Echocardiographic results (LVEF, LVH, and diastolic dysfunction) and clinical heart failure, this study validates the use of specific imaging markers as reliable diagnostic tools in the hemodialysis setting. This helps in distinguishing between simple fluid overload and structural heart disease.

Research Objectives

This study tries to identify the clinical predictors of heart failure among patients undergoing maintenance hemodialysis at Aboud Military Hospital Center in Aden, Yemen.

To identify the strongest independent predictors of heart failure among the studied variables (socio-demographic, clinical, laboratory) to develop a predictive profile for high-risk patients.

The Study Hypotheses

There is a predictive ability among the variables (socio-demographic, clinical laboratory, dialysis factors) with statistical significance of the presence of heart failure in the study sample.

Literature Review

In what follows will provide the literature related to the subject under study:

Definition and Classification

Many definitions of heart failure have been found in the literature. One of the most recent ones refers to HF which is commonly defined as a complex set of symptoms that results from any structural or functional abnormality that affects the ability of one or both ventricles to fill or excrete blood [1]. Clinically, symptoms include shortness of breath, fatigue, and fluid retention. Among patients receiving MHD, the definition of HF often overlaps with the definition of nephrogenic heart syndrome type 4 because chronic kidney disease directly leads to decline in heart function and enlargement of the heart [2].

The global definition of heart failure classifies the syndrome based on the ratio of left ventricular ejection fracture (LVEF) into three types:

1. HF with reduce ejection fraction (HFrEF): LVEF less than 40%.
2. HF with mild reduce ejection fraction (HFmrEF): LVEF 41%–49%.
3. HFpEF: LVEF equal or more than 50%.

HFpEF is the most observed phenotype in patients receiving hemodialysis due to chronic hypertension, increased stiffness of the arteries, and left ventricular hypertrophy [3]. Each of these three types are briefly described in the next section.

1. Heart Failure with Reduce Ejection Fraction (HFrEF)

The definition and diagnostic threshold are clarified below:

Heart failure with reduce ejection fraction (HFrEF) is the systolic component of heart dysfunction. In the category of maintenance hemodialysis, HFrEF is particularly important because it is often the result of end-stage cardiac injury resulting from dialysis. Based on the latest global guidelines, HFrEF is known for the presence of clinical symptoms and signs of heart failure accompanied by less than 40% left ventricular ejection fraction (LVEF) [1], [3]. In people receiving hemodialysis, heart failure with reduce ejection fraction (HFrEF) shows a significant impairment of the heart's ability to contract (pump).

Pathological Drivers in Dialysis

Regarding pathological drivers in dialysis, it has been indicated [4] that while heart failure with reduced ejection fraction (HFrEF) in the broad group is mainly affected by myocardial infarction, its onset in patients with maintenance hemodialysis (MHD) is characterized by distinct mechanisms. Recurring episodes of intradialytic hypotension and rapid fluid removal cause transient ischemia. Over time, this trauma leads to permanent loss of muscle cells and replacement fibrosis, resulting in a decrease in ejection fraction.

- **Uremic cardiomyopathy:** High levels of uremic toxins (such as indoxyl sulfate) directly affect mitochondrial function in heart cells, reducing the strength of the heart's contraction.
- **Coronary artery disease (CAD):** Rapid atherosclerosis and extensive vascular calcification, caused by calcium and phosphate imbalances, are very common in dialysis patients, leading to HFrEF ischemia.

Indications and Clinical Significance

Previous studies have identified several key indicators specific to HFrEF in the dialysis group:

1. **Ultra-high Filtration Rates:** Removal of more than 10–13 ml/kg/hr during washing sessions is significantly associated with a decline in LVEF.
2. **Chronic Anemia:** A chronic lack of hemoglobin leads to a high-yielding condition that eventually leads to the depletion of the heart muscle.
3. **Diabetes Mellitus:** Diabetes mellitus is defined differently by scholars. It has been defined [5] as: Diabetes mellitus is a cluster of metabolic disorders attributable to glucose (blood sugars in the body) dysregulation. Type 1 diabetes mellitus is an autoimmune disorder that destroys the beta cells in the pancreas. This destruction leads to the body's inability to produce insulin, a hormone that is needed to regulate blood glucose (sugars). Type 2 diabetes mellitus is attributable to incremental deficits in insulin production leading to insulin resistance. Hypnosis can be a very beneficial adjunctive treatment for patients with diabetes.

Patients undergoing dialysis have a significantly higher risk of transitioning from conserved EF to HFrEF due to diabetic microvascular disease. HFrEF in the dialysis category carries a much worse prognosis than HFpEF. Patients with LVEF less than 40% have a double risk of sudden cardiac death, and are very sensitive to fluid changes that occur during the long weekend (the two-day gap in dialysis treatment) [6]. Heart failure with a mild reduced ejection fraction (HFmrEF), formerly known as medium-range heart failure, is a transitional and often overlooked category that is highly relevant to the hemodialysis group of patients.

2. Heart Failure with a Mild Reduced in Ejection Fraction (HFmrEF)

The criteria for identification and diagnosis are outlined below: For the 2021 and 2022 ESC guidelines from the AHA/ACC/HFSA, HFmrEF is known to have symptoms and markers of heart failure with a left ventricular ejection fraction between 41% and 49% [1], [3]. To make a definitive diagnosis in dialysis patients, clinical symptoms must be accompanied by objective evidence of structural heart disease (e.g., left atrium enlargement or left ventricular hypertrophy) or elevated natural peptides in the urine (NT-proBNP), preferably measured at the patient's dry weight to rule out simple volume overload.

Phenotypes and Clinical Characteristics

It has been noted [7] that "a clinical phenotype is a manifestation of a disease, condition, or characteristic in a patient that is recorded in a clinical data source (such as an Electronic Health Record), including symptoms, laboratory results, and imaging findings." HFmrEF is often described as an intermediate phenotype, exhibiting characteristics that overlap with both HFrEF and HFpEF. In the continuous hemodialysis group, patients with HFmrEF are usually divided into two categories:

- **Improved Phenotype (HFimpEF):** Patients who had previously HFrEF (LVEF <40%) but showed recovery to optimal medical treatment or successful volume management [1].
- **Deteriorated Phenotype:** Patients with previously conserved function (LVEF =/>50%) with a decline in contraction function due to recurrent myocardial lacerations or the development of uremia.

Prevalence and Risk Factors

In the hemodialysis category, the prevalence of HFmrEF is estimated to be between 13% and 15% [8]. This is lower than the prevalence of HFpEF but represents a large group at risk of subsequent cardiac deterioration. Key indicators identified in recent studies include:

1. **Ischemic Heart Disease (IHD):** Patients with HFmrEF are more likely to develop latent coronary artery disease compared to those with HFpEF.
2. **Old Dialysis:** The length of dialysis duration is associated with the transition from conserved function to a slightly limited range due to accumulated fibrous changes.
3. Anemia and Phosphorus Levels: Chronic anemia and high serum phosphorus are independent indicators of reduced ejection fraction in this group [9].

Predictive Value

Predictive value or sometimes referred as predictive significance can be defined as the ability of a test or data to predict future condition. It is defined [10] as the "predictive value signifies the accuracy of a test or marker in forecasting future outcomes or conditions". Similarly, it has been pointed out [11] that it signifies the ability of a variable or model to accurately forecast a future outcome or behavior. While HFmrEF was previously thought to be a stable intermediate-level state, recent research confirms its dynamic nature. About 25% of HFmrEF patients are eventually descend into the HFrEF class, which carries a much higher risk of death. Conversely, with the introduction of SGLT2 and ARNI inhibitors into dialysis care, a large portion of these patients can achieve remission to a preserved ejection fraction.

3. Heart Failure with Preserved Ejection Fraction (HFpEF)

The criteria for identification and diagnosis are outlined below:

Definition and Diagnostic Criteria

According to the 2021 ESC and 2022 AHA/ACC/HFSA guidelines, HFpEF is defined by signs and symptoms of heart failure accompanied by a Left Ventricular Ejection Fraction (LVEF) =>50% [1], [3]. In the context of dialysis patients, diagnosing HFpEF is particularly challenging because fluid overload can mimic these symptoms. Therefore, a definitive diagnosis requires:

- **Objective Evidence:** Structural heart disease such as Left Atrial Enlargement (LAE) or Left Ventricular Hypertrophy (LVH).
- **Biomarkers:** Elevated Natriuretic Peptides (e.g., NT-proBNP). For hemodialysis patients, these should ideally be measured at dry weight to ensure the elevation is due to cardiac dysfunction rather than simple fluid volume excess.
- **Diastolic Dysfunction:** Evidence of impaired ventricular filling or high filling pressures during diastole.

HFpEF can be defined as a case in which the heart pumps correctly and naturally but its stiffness does not make it fill in properly. HFpEF is often characterized by diastolic dysfunction, where the heart muscle becomes stiff and cannot relax properly, even though the "squeeze" (systolic function) remains normal. In the hemodialysis population, HFpEF is frequently associated with:

- **The Stiff Heart Phenotype:** Driven by chronic pressure overload and systemic inflammation, leading to myocardial fibrosis.
- **Volume Sensitivity:** These patients have a narrow therapeutic window; they are highly sensitive to even minor fluid gains between dialysis sessions, leading to rapid onset of pulmonary edema (often called flash pulmonary edema).

Prevalence and Risk Factors

HFpEF is the most common form of heart failure among patients on maintenance hemodialysis, with a prevalence often exceeding 30% to 50% in this specific population [8].

Key risk factors identified in recent clinical literature include:

- **Chronic Hypertension:** Long-standing high blood pressure is the primary driver of the concentric remodeling seen in HFpEF.
- **Age and Diabetes:** Older patients and those with Type 2 Diabetes are significantly more likely to exhibit the HFpEF phenotype.
- **Arteriovenous (AV) Fistula Flow:** High-flow vascular access can increase cardiac output demands, contributing to "high-output" heart failure symptoms even when the ejection fraction is preserved.
- **Mineral Bone Disorder (MBD):** Elevated calcium-phosphorus products contribute to the calcification of heart valves and the myocardium, increasing cardiac stiffness.

Key Indicators Identified in Recent Studies

Recent data emphasizes that HFpEF in dialysis is not a "mild" condition but carries a high burden of morbidity:

- **Uremic Toxins:** Accumulated toxins in the blood directly promote myocardial stiffness and interstitial fibrosis.
- **Interdialytic Weight Gain (IDWG):** Higher fluctuations in fluid weight are more strongly correlated with HFpEF hospitalizations than with other heart failure subtypes.
- **Systemic Inflammation:** Elevated CRP levels are frequently seen in HFpEF patients, suggesting that systemic inflammation plays a larger role in this phenotype than in HFrEF.

Previous Studies

This section reviews previous studies related to the subject under study. These include studies on prevalence, studies on prevalence and studies on predictors:

In a study [12] conducted at the Bihor County Clinical Emergency Hospital in Oradea, Romania, researchers utilized a retrospective cohort design to evaluate 271 adult patients who had been receiving thrice-weekly maintenance hemodialysis for at least 18 months. By employing the 2021 ESC diagnostic criteria alongside transthoracic echocardiography and a high-threshold NT-proBNP biomarker cut-off of 10,000 pg /mL the study revealed a high heart failure prevalence of 75%. Multivariable analysis identified older age, reduced ejection fraction, and high ultrafiltration rates as the primary independent predictors, ultimately concluding that these cardiac factors are critical drivers of mortality in the dialysis population.

Another study [13] synthesized epidemiological data and clinical registry findings to evaluate the unique landscape of HF within the United States hemodialysis population. The study utilized data from the United States Renal Data System (USRDS), examining large-scale cohorts of patients on maintenance hemodialysis. The methodology focused on the pathophysiology of the "uremic" heart, moving beyond standard clinical classifications to investigate the structural and functional changes induced by end-stage renal disease (ESRD). The researchers evaluated the impact of myocardial stunning, left ventricular hypertrophy (LVH), and vascular calcification as specific drivers of cardiac dysfunction. Statistical evidence was drawn from registry-based

outcomes to identify longitudinal trends in survival and hospitalization. The study reported that approximately 40% of patients have heart failure at the time of dialysis initiation. The analysis identified several unique independent predictors and clinical insights: Myocardial Stunning: Recurrent intradialytic ischemia caused by rapid fluid removal, leading to permanent systolic dysfunction. Mineral Bone Disease: Imbalances in calcium and phosphate that accelerate the calcification of heart valves and large arteries. Dialysis Vintage: The risk of HF-related death increased significantly with the total length of time a patient remained on hemodialysis. The study concluded that heart failure in this population carries a dismal prognosis, with a 3-year mortality rate exceeding 80% following diagnosis. The authors highlighted that traditional heart failure medications often lack strong evidence base in this group, suggesting that meticulous volume control and prevention of intradialytic hypotension are the most effective strategies for reducing cardiac burden.

Another study [14] at the Muhimbili National Hospital in Dar es Salaam, Tanzania, was carried out over a three-month period. This hospital-based cross-sectional study analyzed 160 adult patients who had been on dialysis for at least three months, utilizing the Framingham Criteria for diagnosis and calculating indices for malnutrition and erythropoietin resistance. The findings showed a much lower heart failure prevalence of 10.6%, with the presence of angina, intradialytic hypertension, and anaemia serving as the significant independent predictors, highlighting the role of the Malnutrition-Inflammation Complex Syndrome over traditional risk factors.

Finally, a cross-sectional study conducted in Pakistan [15] examined 142 patients at the PNS Shifa Hospital and King Abdullah Teaching Hospital. The methodology involved clinical pro-formas, dry weight measurements, and laboratory analysis for inflammatory markers like CRP and ferritin. This study reported a heart failure prevalence of 14.8% and identified hypertension, anaemia, and angina as the specific independent predictors. The results further emphasized that heart failure in this cohort is significantly linked to inflammation and erythropoietin resistance, reinforcing the need for integrated cardiac and inflammatory management.

When comparing these studies, a striking disparity in heart failure prevalence emerges, ranging from as low as 10.6% in Tanzania and 14.8% in Pakistan to a staggering 75% in Romania. These differences are largely attributable to the diagnostic methodologies employed: the Romanian study utilized high-sensitivity NT-proBNP biomarkers and 2021 ESC criteria, which likely captured subclinical cases that the clinical Framingham Criteria used in Tanzania might have missed. Despite these regional variations, a significant overlap exists in the identified predictors. Anaemia and hypertension were consistent independent predictors across the Pakistani and Tanzanian cohorts, while hemodynamic stress specifically through high ultrafiltration rates in Romania. Furthermore, the studies in Pakistan and Tanzania both highlighted the Malnutrition-Inflammation. Finally, while the clinical presentation of heart failure may be influenced by local demographics and diagnostic thresholds, the underlying pathophysiology remains rooted in the volatile intersection of fluid management, chronic inflammation, and uremic toxicity.

Research Methodology

This study utilizes a quantitative research approach with an analytical cross-sectional design. Quantitative designs are appropriate [16] when the research objective is to identify factors that influence an outcome or to understand the predictors of a condition. The choice of a cross-sectional design is justified because it allows for the simultaneous assessment of the prevalence of heart failure and its associated predictors among patients on maintenance hemodialysis at a single point in time. Cross-sectional studies are particularly effective [17] for population-based surveys and clinic-based samples to estimate disease frequency and investigate associations between risk factors and health outcomes. Furthermore, this study is "analytical" rather than purely descriptive because it goes beyond reporting prevalence to examine the relationship between various clinical and demographic variables (the predictors) and the presence of heart failure using multivariable analysis [18]. The study is designed to investigate the prevalence and predictors of HF among the MHD population at Abood Military Hospital. Data collection was collected over a six-month period from April, 2025, to July 30, 2025.

Study Setting

The study was conducted at the Dialysis Center of Abood Military Hospital, a major tertiary referral canter in Aden, Yemen, serving a large population from the city and surrounding governorates. Aboud Military Hospital is located in the Khormaksar district, Aden Governorate. It serves as a primary medical hub for the Southern Armed Forces, military personnel, their families, and increasingly, the civilian population of Aden and neighboring governorates (such as Lahj and Abyan). As a military hospital, it has been on the front lines of the humanitarian crisis. It has historically been a center for treating war-wounded individuals. It has Specialized Dialysis Services:

- **The Dialysis Center:** In late 2020, a major renovation of the Dialysis Center was inaugurated. It was equipped with 15 advanced dialysis machines in its first phase, with a capacity to perform approximately 15,000 sessions per year.

- **High Patient Volume:** Because it is one of the few functional, well-equipped centers in the region, it handles a high volume of patients with End-Stage Renal Disease (ESRD), making it an ideal location for a prevalence study on heart failure.
- **Recent Developments and Expansion:** The hospital has undergone significant modernization recently to transform it into a "Military Medical City."

Key expansions include:

- **New Emergency Complex:** Includes general emergency, intensive care units (ICU), and major operating rooms.
- **Diagnostic Capabilities:** The hospital has improved its imaging departments, including the Echocardiography units used to measure LVEF and diastolic dysfunction.
- **Advanced Units:** Foundation stones have recently been laid for specialized kidney and liver transplant departments, signaling its move toward becoming a tertiary referral center.

Study Population

For this study, the target population consists of all patients (51 patients) undergoing maintenance hemodialysis (MHD) therapy in Aden, Yemen. The accessible population included all patients receiving MHD at the Dialysis Center of Abood Military Hospital during the study period.

Study Participants and Eligibility Criteria

In this study, a purposive sampling technique (comprehensive sample) of all available hospitalized patients who had experienced MHD (51 patients). Patients were included if (1) they were 18 years or older, (2) they were in maintenance hemodialysis for more than three months. (3) their condition was stable, (4) they were capable of communication, and (5) agreed to participate in the research (6) documented as performed ecocadiograoghy report. Patients were excluded if they (1) had undergone heart surgery; (2) had a history of heart valve disease, cancer. Nine patients were eligible but were not included in the study because they did not want to respond to questions. The researcher informed all of the participants about the aim of the study. After being informed and confirmed stable, the patients were approached. Given the specific nature of the clinical setting and the defined study period, a purposive sampling technique.

Data Collection Procedures

Data collection was carried out using a multi-modal approach consisting of structured interviews, laboratory analysis, patients records and echocardiography report.

Patient Interview Form

A structured interview in accordance with the related literature is used collect data. The patients structured interviews were included socio-demographic characteristics about (sex, age, occupation, smoking, Qat chewing) and Clinical information (history of hypertension, diabetes mellitus and coronary heart disease (angina)and dialysis vintage (duration of haemodialysis in months, type of arteriovenous access, pre-dialytic hypertension. And cardiac failure symptoms according to Framingham criteria. Measuring dry weight at the end of dialysis session and their heights were determined using a weighing standard scale and stadiometer respectively. To assess the severity of heart failure symptoms, the New York Heart Association (NYHA) functional class was determined through a structured patient interview. The NYHA classification is a widely validated tool for gauging the impact of heart failure on a patient's functional status [1]. AHA stages of heart failure and heart failure subtypes are included.

Laboratory Data (Documents)

To ensure accuracy, pre-dialysis blood samples were collected and analyzed at the central laboratory of Abood Military Hospital. The following standardized methods were employed:

1. **Haemoglobin (Hb):** Measured via the photometric method.
2. **Serum Electrolytes (Sodium, Potassium):** Analyzed using Ion-Selective Electrode (ISE).
3. **Serum Urea, and Creatinine:** Measured using photometric methods.

Echocardiography

A comprehensive transthoracic echocardiogram was performed 24–48 hours post-dialysis to ensure the patient was at their "dry weight," minimizing the impact of fluid overload on measurements [19]. To reduce inter-observer variability, all examinations were conducted by a single experienced cardiologist blinded to the patients' clinical data. The protocol included:

1. **Left Ventricular Ejection Fraction (LVEF):** Measured using the Simpson’s biplane method.
2. **Left Ventricular Mass Index (LVMI):** Calculated via the linear method and indexed to body surface area (LVMI) to define Left Ventricular Hypertrophy (LVH).
3. **Diastolic Function:** Assessed using pulsed-wave and tissue Doppler imaging in accordance with the American Society of Echocardiography guidelines [20].

Diagnosis of Heart Failure (Outcome Variable)

The clinical diagnosis of Heart Failure (HF) was established using the Framingham Criteria, which is a gold standard in epidemiological research. Diagnosis required the presence of at least two major criteria (including paroxysmal nocturnal dyspnea and orthopnia) or one of these two majors and two minor criteria (night cough, exertional dyspnea and ankle edema) concurrently [21]. And echocardiography findings (LVEF of less than 50% OR equal or more than 50% with diastolic dysfunction and presence of left ventricular hypertrophy).

Data Management and Statistical Analysis

Data is entered into and analyzed using IBM SPSS Statistics for Windows, Version 21.0. Descriptive statistics is used to get frequencies and percentages for categorical variables. The prevalence of HF is calculated as a proportion with a 95% confidence interval (CI). Multivariable binary logistic regression is performed to identify independent predictors of HF. Variables with a p-value <0.05. Results are expressed as adjusted odds ratios (aOR) with 95% CI. A two-tailed p-value < 0.05 is considered statistically significant.

Data Analysis and Discussion

A binary logistic regression analysis was conducted to identify independent predictors of heart failure among patients undergoing maintenance hemodialysis, using the Framingham criteria as the diagnostic standard. The logistic regression model demonstrated good discriminatory ability. The overall classification accuracy of the model was (84.3%), with a sensitivity of 91.2% for correctly identifying patients with heart failure and a specificity of 70.6% for correctly classifying patients without heart failure. The cut-off value for classification was set at 0.50, indicating adequate balance between sensitivity and specificity.

Independent Predictors of Heart Failure

After adjustment for potential confounders, smoking and hypertension emerged as statistically significant independent predictors of heart failure. Smoking was significantly associated with heart failure, with smokers having 11.53 times higher odds of developing heart failure compared with nonsmokers (OR = 11.53, 95% CI: 0.55–248.18, p = 0.028). Similarly, hypertension was found to be a strong independent predictor. Patients with hypertension had 14.03 times higher odds of heart failure compared with normotensive patients (OR = 14.03, 95% CI: 0.73–269.35, p = 0.035). Other variables, including age, sex, diabetes mellitus, khat chewing, anaemia, duration of haemodialysis, type of vascular access, angina and hyperkalemia, did not show statistically significant associations with heart failure in the multivariable model (p > 0.05).

Table (1): Multivariable Logistic Regression Analysis of Predictors of Heart Failure

Variable		Exp(Odds Ratio (OR)B)	95% C.I.for EXP(B)		p-value
			Lower	Upper	
Step 1[a]	Agegroup	3.182	0.179	56.472	0.43
	Sex	0.581	0.056	5.982	0.648
	Khat	1.849	0.105	32.562	0.675
	Smoker	11.532	0.536	248.176	0.023
	HTN	14.031	0.729	269.954	0.006
	DM	1.581	0.215	11.638	0.653
	Angina	176250535.8	0	.	0.999
	DialDuration	7.446	0.485	114.352	0.15
	AV_Access	254355304.8	0	.	0.999
	anaemia	795083605.5	0	.	0.999
	Hyperkalemia	0.851	0.08	9.085	0.894
	Constant	0			0.998

Discussion

This study identified smoking and hypertension as the only independent predictors of heart failure among patients receiving maintenance hemodialysis. The association between smoking and heart failure observed in this study is consistent with previous research demonstrating that smoking contributes to endothelial dysfunction, accelerated atherosclerosis, oxidative stress, and adverse cardiac remodelling. These mechanisms are particularly detrimental in patients with chronic kidney disease, who already have a high cardiovascular burden [22]. Hypertension emerged as the strongest predictor of heart failure in the present study. Persistent elevation of blood pressure leads to left ventricular hypertrophy, impaired diastolic function, and increased myocardial oxygen demand, ultimately resulting in heart failure. This association has been consistently reported in hemodialysis populations [23]. In contrast, variables such as age, sex, diabetes mellitus, anaemia, duration of haemodialysis, and type of vascular access did not retain statistical significance in the multivariable analysis. This finding may be explained by the relatively small sample size, collinearity between cardiovascular risk factors, or the dominant effect of hypertension and smoking. Similar observations have been reported in previous hemodialysis studies [24]. The findings of this study underscore the importance of strict blood pressure control and the implementation of effective smoking cessation programmes to reduce the burden of heart failure among hemodialysis patients, particularly in low-resource settings such as Yemen.

Main Findings

The binary logistic regression model demonstrated a strong predictive ability for heart failure within the study sample. Its performance is characterized by the following metrics:

- **Overall Accuracy:** 84.3%
- **Sensitivity:** 91.2% (High ability to identify patients who actually have heart failure).
- **Specificity:** 70.6% (Moderate ability to identify patients who do not have heart failure).
- **Cut-off Value:** 0.50 (Indicates a balanced model for classification).

While the hypothesis suggests a broad predictive ability across many categories, the multivariable analysis narrowed the statistical significance down to two primary independent predictors:

Table (2): statistical significance

Category	Significant Variable	Odds Ratio (OR)	Significance (p-value)
Clinical/Co-morbidity	Hypertension	14.03	0.006
Socio-demographic/Life	Smoking	11.53	0.023

The hypertension is the strongest predictor in this model, followed closely by smoking. Both drastically increase the odds of heart failure in hemodialysis patients. It indicates that patients with hypertension are 14 times more likely to develop heart failure compared to those without hypertension. Many variables mentioned did not show independent statistical significance ($p > 0.05$) when adjusted in the multivariable model:

- **Socio-demographics:** Age and Sex.
- **Clinical/Laboratory:** Diabetes Mellitus, Anaemia, and Hyperkalemia.
- **Dialysis Factors:** Duration of hemodialysis and Type of vascular access.
- **Lifestyle:** Khat chewing.

As noted in the discussion, the lack of significance for these variables could be due to:

1. **Small Sample Size:** There may not have been enough participants to detect smaller effects.
2. **Collinearity:** Factors like age or diabetes might be so closely linked to hypertension that hypertension "absorbs" the statistical power in the model.
3. **Dominance:** Smoking and hypertension have such a profound impact on heart health in this group that they overshadow other risk factors.

Final Conclusion on the Hypothesis

The hypothesis is proved partially true. There is indeed a statistically significant predictive ability within the model, but it is driven almost entirely by hypertension and smoking rather than the full suite of socio-demographic and dialysis-related factors.

Limitation of the Study

Limitations can be defined as the factors or constraints that affect the research that are out of the researcher control. Acknowledging the limitations of a study is a hallmark of academic integrity, as it demonstrates the researcher's awareness of the scope and context of the findings. Every research project, regardless of its rigor, faces constraints that may impact the generalizability or depth of its results. These limitations often stem from methodological choices, such as sample size, time constraints, or the availability of resources. Researchers must be transparent about these boundaries [16]; "the limitations section of a study provides an opportunity for the researcher to identify potential weaknesses in the study and to suggest how these weaknesses might be addressed in future research" (p. 210). By identifying these gaps, researchers not only protect their work from over-interpretation but also provide a roadmap for future scholars to build upon their work, ensuring that the scientific process remains iterative and self-correcting. The limitation of this study is that the study relied on a small sample size that limits the ability to generalize the findings. Also, the study relied mainly on self-reported data, which may involve patients' bias. NT-proBNP, albumin lipid profile tests were not included in the tests of the study as it was not available. The study is limited to Aboud Military Hospital Center in Aden as other centers in Aden do not have echocardiography.

Delimitations of the Study

As limitations address the weaknesses or constraints a researcher cannot control, delimitations refer to the intentional boundaries set by the researcher to narrow the scope of the study. These choices such as the specific geographic location, the age range of participants, or the specific variables being tested—are made to ensure the research remains manageable and focused. By clearly defining what the study will and will not cover, the researcher provides a clear "map" of the investigation's reach. It is explained [25] that "delimitations are those characteristics that limit the scope and define the boundaries of the study. The delimitations are in the control... [they] flow from the specific problem addressed " (p. 2). Effectively communicating these boundaries ensures that the reader understands the specific context of the findings and does not expect the data to apply to scenarios or populations that were intentionally excluded from the research design. The delimitations of this study are related to excluding sodium as it was not included because patients did not do them as they are very expensive.

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مقالة بحثية

العوامل المتنبئة بحدوث فشل القلب لدى المرضى الخاضعين للعلاج بالغسيل الكلوي الدوري

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المُلخّص

هدفت هذه الدراسة إلى تحديد مدى انتشار ومؤشرات مرض قصور القلب بين المرضى الذين يخضعون لعلاج غسيل الكلى في مركز الغسيل الكلوي بمستشفى عبود العسكري، وهو مركز إحالة رئيسي في محافظة عدن، اليمن. اعتمدت الدراسة على التصميم البحثي المستعرض التحليلي الذي اعتمد على عينة الدراسة التي تمثلت بالمرضى الذين خضعوا لغسيل الكلى في المركز (51 مريضا). تم جمع البيانات باستخدام نموذج المقابلة مقابلة المريض، بيانات المختبر (الوثائق)، تخطيط صدى القلب وتشخيص مرض قصور القلب. لتحليل البيانات تم استخدام برنامج التحليل الاحصائي تم استخدام SPSS v. 21. بناء على تحليل البيانات، وجدت الدراسة قدرة تنبؤية قوية لمرض قصور القلب ضمن عينة الدراسة حيث أثبتت الدراسة الفرضية الأولى التي تقول "هناك انتشار مرتفع لمرض قصور القلب بين المرضى في العينة (مرضى غسيل الكلى) في مركز غسيل الكلى في مستشفى عبود العسكري في عدن، اليمن. وجدت الدراسة أيضا أن هناك عبئا عاليا حيث أن 67.90% من العينة (المرضى) استوفوا معايير فرامينغهام لمرض قصور القلب هيمنة قصور القلب الانبساطي بأغلبية كبيرة بلغت (75.50%) وهذا يشير إلى أن مرض قصور القلب الانبساطي وليس قصور في المضخة، هو الدافع الأساسي للأعراض. أظهرت الدراسة ان 86.80% من المرضى لديهم تضخم في البطين الأيسر، وهو ما يرتبط بمعدل قصور القلب الانبساطي المرتفع. فيما يتعلق بشدة المرض السريري وجدت الدراسة بان 66% من المرضى هي في المراحل المتقدمة (المرحلتين ج ود) من مراحل تصنيف مرض قصور القلب. تم إثبات الفرضية الثانية المتعلقة بالقدرة التنبؤية جزئيا حيث حدد الانحدار اللوجستي الثنائي عاملين مستقلين محددين ذوي دلالة إحصائية محددة: (1) مرتبطا بارتفاع ضغط الدم بنسبة الأرجحية بلغت 14.03، بمعنى ان مرضى ارتفاع ضغط الدم أكثر عرضة ب 14 مرة للإصابة بمرض قصور القلب وكان هذا أقوى مؤشر في الدراسة. (2) التدخين: المدخنين معرضين للإصابة بمرض قصور القلب بنسبة 11.53 مرة مقارنة بغير المدخنين. كما أظهرت الدراسة بان عوامل أخرى مثل العمر والجنس ومرض السكري ومضغ القات لها علاقة ارتباط في البيانات الوصفية لكنها لم تصل إلى دلالة إحصائية كمؤشرات مستقلة في النموذج متعدد المتغيرات، ويرجح أن ذلك بسبب التأثير السائد لضغط الدم والتدخين. بلغت الدقة الإجمالية 84.3%. اختتمت الدراسة بمجموعة من التوصيات تتعلق بإدارة ضغط الدم، والفحص المبكر لقياس صدى القلب، وتحسين فقر الدم، وبرامج الإقلاع عن التدخين، التوعية بمخاطر تناول القات، والدعم الغذائي.

الكلمات المفتاحية: مرض قصور القلب؛ المؤشرات المتنبئة؛ غسيل الكلى الدموي المستمر.

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