

# Bayesian Analysis of Financial Impact of Cardiovascular Diseases in LAUTECH Teaching, Hospital, Oyo State, Nigeria

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© 2026 جامعة العلوم والتكنولوجيا، المركز الرئيس عدن، اليمن. يمكن إعادة استخدام المادة المنشورة حسب رخصة مؤسسة المشاع الإبداعي شريطة الاستشهاد بالمؤلف والمجلة.

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**Abstract**— cardiovascular diseases (CVDs) remain a major health challenge in Nigeria that leads to high morbidity, mortality, and financial burden. Low- and middle-income countries (LMIC), with no exception to Nigeria, are suffering from high hospitalization costs for treating CVDs. The cost leads to Monthly Financial Loss (MFL) and prolonged treatments. In literature, there is a dearth of study on Financial Impact (FI) for treating CVDs in Nigeria.

**Objective**— This work is aimed at evaluating the FI where there is prior information about CVDs at LAUTECH Teaching Hospital (LTH).

**Method**— Bayesian Multinomial Logistic Regression (BMLR) is explored to evaluate the MFL incurred by CVD patients at LTH and the type of CVDs contributing to it.

**Result**— The results show that there is a probability of having MFL among different CVD patients in LTH.

**Conclusion**— Policymakers in health sectors should implement targeted financial aid for the treatment of CVDs to address the different MFL.

**Keywords**— Multinomial logistic, financial aid, financial loss, prior information, and Bayesian.

## Introduction

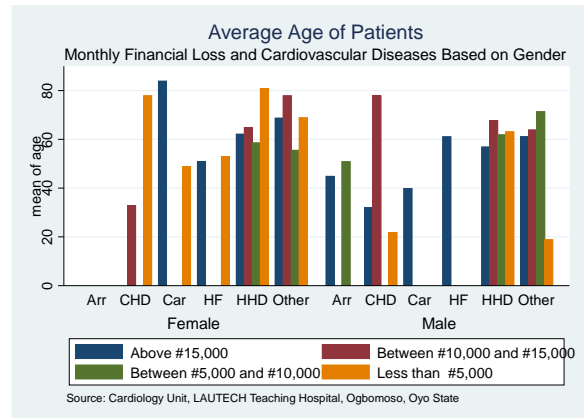
The cost of treating cardiovascular diseases (CVDs) is a significant financial burden in Nigeria. Studies have documented substantial out-of-pocket expenditures for cardiovascular care that strain household finances (Adeniji et al., 2022; Ogah et al., 2014). These diseases are also associated with psychological distress that necessitates integrated mental health support (Borkowski et al., 2024; Marchetti et al., 2024; Vaccarino & Bremner, 2025). Some studies report the financial impact of CVDs like diabetes and hypertension (Ogah et al., 2023; Akumiah et al., 2023). CVD treatment is challenging due to the lack of standard methodologies, variations in drug

and test expenses, inadequate data, and informal caregiving costs (Mallah et al., 2023; Akumiah et al., 2023). The CVDs account for approximately 10% of deaths and 3.8% of disability-adjusted life-years in Nigeria, necessitating targeted interventions (Ogah et al., 2023). In literature, there are highlights for the potential of lifestyle modifications (Carola et al., 2024), generic medications (Akumiah et al., 2023), and telemedicine and digital health initiatives (Krittawong et al., 2023; Oseran et al., 2024) in reducing costs and improving outcomes of CVDs. Methods of analysis previously used to assess the financial implications of CVDs include cost-of-illness approaches, Markov models, and microsimulation models (Kostova et al., 2025; Mallah et al., 2023). Financial loss associated with CVDs is not limited to adults. Families caring for children with congenital heart disease also face high pre-surgical management costs, with median out-of-pocket costs of \$60 and overall 39.9% experiencing catastrophic healthcare expenditure (Yap et al., 2023). Average annual direct and indirect outpatient Out-of-Pocket (OOP) costs for CVD patients in Ibadan remain substantial, and rehabilitative care after discharge adds significant financial loss. These expenses are significant, especially when compared to the national minimum wage and average household incomes, and are often unaffordable for many families (Adeniji, 2021). The OOP payments frequently lead to catastrophic health expenditures for which many families fall below the poverty line as a direct result of paying for CVD care in Nigeria. Between 2000 and 2019, over 150 million people in Africa were pushed into or deeper into poverty due to out-of-pocket healthcare payments (Makoka & Kaluwa, 2024; WHO Africa, 2023). Major factors contributing to these expenses are hospitalization and transportation, for which about 36.1% of families experience financial loss. This loss is worsened by limited insurance coverage and high out-of-pocket payments, leading to care deferral and trade-offs with basic needs (Zafar et al., 2021). Socioeconomic factors

like poverty, unemployment, and limited healthcare access contribute to CVD occurrence, with regional variations as risk factors (Akinkugbe et al., 2022). The prevalence of CVDs has been a major health concern in Nigeria as a low- and middle-income country, with a hypertension prevalence of 30.6% and CVD risk factors present in over 60% of the population (Ogah et al., 2023; Bamidele et al., 2024). Findings from recent studies revealed that OOP payments ranged from 3.9% to 54.6% of household expenditures. Treating CVDs doubled health expenditures, resulting in increased poverty headcount among affected households, with out-of-pocket health spending representing 40% or more of total health expenditure in many African countries (Makoka & Kaluwa, 2024; Olasehinde et al., 2024). Recent reviews of the implications of Nigeria's worsening economic indices on cardiovascular health reveal how low government spending is on healthcare. The healthcare budget of \$2.6 billion in 2023 remains far below the recommended 15% of the national budget for health care (Nigeria Healthcare Market Report, 2023). The cost of healthcare and cardiovascular medications has risen due to currency devaluation, increasing the financial loss of patients. Yusuf et al. (2025) estimated that the direct cost of treating CVDs in Nigeria is about \$45 billion annually, with indirect costs exceeding \$100 billion. Healthcare utilization, disease prevalence, and lifestyle behaviors were identified as key drivers of these costs. The study stressed the importance of prevention programs, improved healthcare access, and targeted interventions for vulnerable populations to reduce the financial loss of CVDs. Out-of-sample information has not been fully explored to address the cost of healthcare delivery for CVD patients in LAUTECH Teaching Hospital, Ogbomoso, Oyo State, Nigeria.

**Materials and Methods**

The datasets were collected on financial loss of CVDs treatment at the Cardiology unit of LAUTECH Teaching Hospital. The designed questionnaire was administered to CVD patients to assess different levels of MFL incurred for treating CVDs. MFL is a multinomially ordered response variable with different CVDs as explanatory variables. These levels of MFL incurred by patients are less than #5,000, between #5,000 and #10,000, between #10,000 and #15,000 and above #15,000. The CVDs considered are Heart Failure (HF), Cardiomyopathy (Car), Hypertensive Heart Disease (HHD), Arrhythmias (Arr), and Coronary Heart Disease (CHD). The Bayesian MFL model was developed using multinomial logistic regression. A likelihood function for MFL model parameters with the normal prior was constructed.



**Figure 1:** Average age of patients suffering from cardiovascular diseases at LAUTECH Teaching Hospital, Ogbomoso, Oyo State, Nigeria.

Figure 1 contains the average age of the patients and MFL incurred during treatment of different CVDs based on gender. The figure reveals that female patients above 60 years of age spent less than #5,000 and above #15,000 for treating CHD, HHD, and Car, respectively, compared to the male gender. Males above 60 years of age spent between #10,000 and #15,000 for treating CHD as opposed to the female gender. Both genders above 20 years who suffered from any of the above-mentioned CVDs incurred some form of MFL. However, females of any age in the study did not suffer from ARR and did not incur MFL.

**Likelihood function Monthly Financially Loss Model Parameters**

The logistic model is generalized to allow more than two possible outcomes, with MFL given HF, Car, HHD, Arr, and CHD that models the probability of each level of MFL by

$$p_j(CVDs) = \frac{e^{\theta_0 + \theta_1 HF + \theta_2 Car + \theta_3 HHD + \theta_4 Arr + \theta_5 CHD}}{1 + e^{\theta_0 + \theta_1 HF + \theta_2 Car + \theta_3 HHD + \theta_4 Arr + \theta_5 CHD}} \tag{1}$$

For j=1,2,3,4

$$p_j(CVDs) = \frac{1}{1 + e^{\theta_0 + \theta_1 HF + \theta_2 Car + \theta_3 HHD + \theta_4 Arr + \theta_5 CHD}} \tag{2}$$

$$\frac{p_j(CVDs)}{p_j(CVDs)} = e^{\theta_0 + \theta_1 HF + \theta_2 Car + \theta_3 HHD + \theta_4 Arr + \theta_5 CHD} \tag{3}$$

Applying a logarithm to both sides of equation (3) gives

$$MFL_i = \log \frac{p_j(CVDs)}{p_j(CVDs)} = \theta_0 + \theta_1 HF + \theta_2 Car + \theta_3 HHD + \theta_4 Arr + \theta_5 CHD \tag{4}$$

Where the sum of the probabilities,  $\sum_{j=1}^J p_j$  (CVDs) is 1.

Then, likelihood function of MFL model parameter is defined as follows;

$$p(MFL_j | \hat{\theta}_j^{MFL_j}) = \frac{n!}{MFL_1! MFL_2! \dots MFL_J!} \theta_1^{MFL_1} \theta_2^{MFL_2} \dots \theta_J^{MFL_J}$$

$$= \frac{n!}{\prod_{j=1}^J MFL_j!} \prod_{j=1}^J \theta_j^{MFL_j}$$

(5)

**Prior Specification for Monthly Financially Loss Model Parameters**

The choice of prior is always a major problem in the Bayesian method. Careful attention must be given to prior selection in the study of the MFL model that follows normal distribution.

$$p(\hat{\theta}_j^{MFL_j}) = \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{-\frac{(\hat{\theta}_j^{MFL_j} - \theta)^2}{2\sigma_j^2}}$$

(6)

where the distribution is restricted to nonnegative  $\theta_j$ 's with  $\sum_{j=1}^J \hat{\theta}_j^{MFL_j} = 1$ .

**Posterior distribution of monthly financial loss model parameters**

The posterior distribution is obtained by multiplying the multinomial distribution of the FI model, equation (4), by the normal prior for each level of MFL, equation (6)

$$p(\hat{\theta}_j^{MFL_j} / MFL_j) \times p(MFL_j / \hat{\theta}_j^{MFL_j}) \times p(\hat{\theta}_j^{MFL_j})$$

(7)

$$p(\hat{\theta}_j^{MFL_j} / MFL) = \left( \frac{n!}{\prod_{j=1}^J MFL_j!} \prod_{j=1}^J \theta_j^{MFL_j} \right) \times \left( \frac{1}{\sqrt{2\pi\sigma_j^2}} e^{-\frac{(\hat{\theta}_j^{MFL_j} - \theta)^2}{2\sigma_j^2}} \right)$$

(8)

Setting aside  $\frac{n!}{\prod_{j=1}^J MFL_j!}$  and  $\frac{1}{\sqrt{2\pi\sigma_j^2}}$  as constants

$$p(\hat{\theta}_j^{MFL_j} / MFL) = \left( \prod_{j=1}^J \theta_j^{MFL_j} \right) \times \left( e^{-\frac{(\hat{\theta}_j^{MFL_j} - \theta)^2}{2\sigma_j^2}} \right)$$

(9)

The resulting posterior distribution of equation (9) does not have a known form of distribution. Hence, MCMC is now explored to obtain a full conditional for MFL model parameters with the aid of the STATA program.

**Table 1:** Results of Bayesian Monthly Financial Loss based on CVDs

	Heart Related Diseases	Pst Mean	Pst Std	CI
<b>Between #5,000 and #10,000</b>	Coronary heart disease	-105.8884	61.39319	-235.5602 -9.654674
	Heart failure	-58.38774	42.92415	-163.9278 -2.555481
	Cardiomyopathy	-51.34601	42.99961	-169.6584 -3.16749
	Arrhythmias	42.03214	11.6078	21.98072 59.98345
	Hypertensive Heart Disease	-1.638521	1.292125	-4.473395 .6329073
<b>Between #10,000 and #15,000</b>	Coronary heart disease	-.6995832	1.399534	-3.406624 2.105529
	Heart failure	-79.04218	60.72229	-225.5686 -3.40618
	Cardiomyopathy	-95.97835	74.31187	-293.3339 -4.156425
	Arrhythmias	-56.3724	65.04538	-190.8768 45.87913
	Hypertensive Heart Disease	-.0539555	1.163292	-2.266843 2.270779
<b>Above #15,000</b>	Coronary heart disease	-2.952576	1.497765	-5.827893 0.0926834
	Heart failure	.9324346	1.470483	-1.640465 4.01432
	Cardiomyopathy	-.617353	1.490205	-3.50783 2.311653
	Arrhythmias	41.18514	11.66404	21.64769 59.42994
	Hypertensive Heart Disease	-.556505	1.008237	-2.430013 1.398166

Table 1 contains the posterior means, standard deviations, and credible intervals for CVDs as covariates for each level of MFL, with less than #5,000 as the base category in the study. The posterior means credible intervals of between #5,000 and #10,000 and above #15,000 are [(42.03214), 21.98072 59.98345] and [(41.18514),

21.64769 59.42994] respectively. This implies that only arrhythmias significantly contribute to MFL for between #5k and #10 and above #15. It shows that arrhythmias add to MFL for treating heart-related diseases at the hospital, while all other considered heart-related diseases negatively and insignificantly impact MFL.

**Table 2:** Relative Risk of Cardiovascular Diseases on Monthly Financial Loss

Cardiovascular diseases	Between #5,000 and #10,000	Between #5,000 and #10,000	Above #15,000
Coronary Heart Disease	0.001181	1.35083	0.157291
Heart Failure	0.043837	0.01778	9.860379
Cardiomyopathy	0.017338	0.02610	1.507697
Arrhythmias	6.510000	1.08000	1.540000
Hypertensive Heart Disease	0.414929	1.862817	0.948375

Table 2 contains values of Relative Risk Ratio (RRR) of the considered CVDs on MFL, obtained using Bayesian Multinomial Logistic Regression (BMLR) with which Dirichlet prior was incorporated. The obtained RRR for Between #5,000 and #10,000 are 0.001181, 0.043837, 0.017338, 6.510000, 0.414929; for Between #5,000 and #10,000 are 1.35083, 0.01778, 0.02610, 1.08000, and 1.862817; and for Above #15,000, they are 0.157291, 9.860379, 1.507697, 1.540000, and 0.948375 for CHD, HF, Car, Arr, and HHD, respectively. Findings in Table 2 reveal that Arr has a high likelihood of MFL for Between #5,000 and #10,000(6.510000), Between #5,000 and #10,000 (1.08000), and Above #15,000 (1.540000) when compared with Less than #5,000. CHD and HHD have a high likelihood of MFL between #5,000 and #10,000, with 1.35083 and 1.862817, respectively. Also, HF and Car have a likelihood of MFL with above #15,000 for 9.860379 and 1.507697, respectively.

**Discussion of results**

The CVDs remain major risk factors for MFL for patients in Ogbomoso of Oyo State, Nigeria. Results obtained from the analysis revealed that CVDs contribute to MFL (Abegunde *et al.*, 2017). Especially, Arr has a high likelihood of causing MFL among patients. Also, this implies Arr significantly and highly contributes to low MFL. However, HF and Car have a high likelihood of causing a high MFL (Ogundipe *et al.*, 2020). The cost of buying drugs, test expenses for treating CVDs,

inadequate data, and informal caregiving costs are far beyond the reach of the patients and hospital management.

**Conclusion**

This study focused on monthly financial loss incurred for treating cardiovascular diseases (CVDs) at LAUTECH Teaching Hospital, Ogbomoso, Oyo State, Nigeria. Instead of attempting a complete review of existing methods, the study focused on developing a Bayesian MFL model for addressing important inference problems associated with a dearth of prior information about different CVDs. The choice of normal prior incorporated into the MFL model is arbitrarily subjective, leading to the absence of Dirichlet prior in the posterior simulation. This makes posterior simulation computationally difficult. An aspect excluded from the study is computational concerns for which use of MCMC is then appropriately applied to derive posterior simulators for the MFL model with the aid of STATA. It is obvious from the study that patients suffering from any kind of cardiovascular disease experienced monthly financial loss in LAUTECH Teaching Hospital. Consequently, the likelihood of experiencing monthly financial loss is low, moderate, and high when patients are having cardiovascular diseases. Also, the cost of treating CVD diseases and ongoing care in the hospital leads to significant monthly financial loss, increased mental illness, and lack of access to necessary health services.

**Summary of Credit Author Statements**

Author's Name	Author's Contribution
Abdullahi O. Olakehinde, Adewale P. Onatunji	Conceptualization
Adewale P. Onatunji, Abdullahi O. Olakehinde	Introduction
Adewale P. Onatunji	Materials and Methods
Adewale P. Onatunji, Oladapo A. Olalude	Analysis and Interpretation for the work
Summayah O. Ibrahim	Discussion of Results and Conclusion
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**Authors' Contributions**

Abdullahi O. Olakehinde and Adewale P. Onatunji contributed to the conceptualization of the study. The introduction was jointly prepared by Adewale P. Onatunji and Abdullahi O. Olakehinde. The materials and methods section was developed by Adewale P. Onatunji. Analysis and interpretation of the data were carried out by Adewale P. Onatunji and Oladapo A. Olalude. The discussion of results and conclusion were prepared by Summayah O. Ibrahim. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors

**Conflict of Interest**

The authors declare that there is no conflict of interest.

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