

Burden of newly diagnosed hypertension in Burundi and 10-year cardiovascular risk: A Bayesian logistic regression and Framingham score-based study

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Burden of newly diagnosed hypertension in Burundi and 10-year cardiovascular risk: A Bayesian logistic regression and Framingham score-based study

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Summary

Background: Arterial hypertension is a major global public health concern. It coexists with other non-communicable and communicable diseases in Burundi, creating complex health challenges difficult to address. We aimed to assess the burden of newly diagnosed hypertension, identify associated risk factors, and assess 10-year cardiovascular risk among hypertensive and non-hypertensive patients. Knowing at-risk populations and level of risk could guide evidence-based interventions.

Methods: We conducted a modelling study on 714 patients admitted at Kamenge Teaching Hospital between January 2018 and December 2022. Retrospective data were obtained from medical records. Bayesian belief update methods, Bayesian logistic regression with bootstrapping, and Bayesian linear models were used to respectively estimate prevalence, risk factors, and associations between diastolic blood pressure (DBP) and cardiovascular risk. The 10-year cardiovascular risk was evaluated using the Canadian Framingham Risk Score.

Findings: The prevalence of newly diagnosed hypertension was 16.9% (95% CrI: 14.2–19.7). Higher rates were observed among women (18%), patients aged 40–59 (21.3%) and ≥ 60 years (33.9%), those with higher education (up to 28.9%), and individuals with obesity, overweight, or family history of hypertension. Significant predictors included age ≥ 40 , tobacco use, higher education, and excess weight. Moderate or severe 10-year cardiovascular risk was found in 24.9% of patients, with more than 60% of hypertensive patients classified as high risk. DBP showed a positive correlation with cardiovascular risk in both hypertensive and non-hypertensive groups.

Interpretation: Newly detected hypertension and its strong association with elevated cardiovascular risk highlight missed opportunities for early diagnosis and prevention. Targeted screening and management of modifiable risk factors could reduce cardiovascular risk in this population and support national efforts to curb the growing burden of non-communicable diseases in Burundi.

Conclusion: The burden of newly diagnosed hypertension and its association with increased cardiovascular risk underscore the need for systematic screening, early diagnosis, and preventive strategies in Burundi. Interventions addressing modifiable risk factors could support national policies and resource allocation to reduce cardiovascular disease burden in line with the 2030 agenda.

Keywords: *Newly Diagnosed Hypertension, Cardiovascular Risk, Framingham Risk Score, Bayesian Modelling, Burundi*

Research in context

Evidence before this study

Africa is experiencing an epidemiological transition marked by a rapid increase of non-communicable diseases with cardiovascular diseases emerging as a substantial public health challenge in the region. We searched PubMed and Google scholar for published papers (in English) between Jan 1, 2000, and Dec 31, 2022, using the terms (“hypertension” or “high blood pressure”) and (“Burundi” or “East Africa”) and (“risk factors” or “cardiovascular risk”) and “model”. Few studies reported the prevalence of newly diagnosed hypertension in Burundi or assessed 10-year cardiovascular risk among hypertensive and non-hypertensive patients. Existing evidence mainly described cross-sectional prevalence or hospital-based data, with limited evaluation of cardiovascular risk stratification. No studies comprehensively combined newly diagnosed hypertension, associated predictors, and 10-year cardiovascular risk in this setting.

Added value of this study

We assessed newly diagnosed hypertension in 714 patients admitted to a tertiary hospital in Burundi and identified risk factors. We also quantified 10-year cardiovascular risk using the Canadian Framingham Risk Score, showing that 25% of patients have a moderate to severe risk of cardiovascular risk (CVD) with over 60% of hypertensive patients at high risk. Our risk assessment in a low-resource setting provides actionable insights for targeted prevention.

Implications of all the available evidence

The relatively high prevalence of newly diagnosed hypertension and its strong association with cardiovascular risk highlight missed opportunities for early detection and prevention. Systematic screening and interventions targeting modifiable risk factors could reduce cardiovascular disease burden. These findings support national strategies to strengthen non-communicable disease prevention in Burundi and other low-resource settings.

1.Introduction

Arterial hypertension is a major public health threat[1, 2], contributing to the growing burden of cardiovascular diseases (CVDs) [1, 3, 4]. In Burundi, the age-standardized prevalence of hypertension among adults aged 30–79 years exceeds the global average, with women exhibiting higher rates than men[5]. Burundi has a high burden of both communicable and non-communicable diseases (NCDs), with the latter making up 37% of deaths in 2019. This coexistence creates a complex situation that is difficult to address, contributing to a persistently high incidence of cardiovascular diseases, with more than 300 cases per 100,000 inhabitants since 2017[6].

After the 2023 World Health Organization (WHO) Global Report highlighted this growing global burden [7], the recent Global Burden Diseases (GBD) study showed the high systolic blood pressure (HSBP) to be the first leading risk factors for early deaths and poor health globally[8].The prevalence of HSBP among adults is around 40% , and 1.13 billion people were estimated to be living with various forms of hypertension [9, 10]. Furthermore, adults suffering from hypertension are expected to reach 1.56 billion this 2025 year[11].Forecasts suggest that between 2022 and 2045, the total number of deaths and disability-adjusted life years (DALYs) will keep increasing[12].

According to the WHO Global Health Observatory data, the highest prevalence of arterial hypertension is in Africa (46%), followed by the Americas (35%) and other regions[13]. The number of deaths caused by hypertension-related cardiovascular diseases among young adults worldwide was 640,239 in 2019, representing an increase of 43.0% compared to 1990 [14]. The 2025 Global report on hypertension highlights the urgent need to scale up detection, treatment, and control of hypertension, especially at the primary health care level. Early diagnosis and treatment of high blood pressure could reduce cardiovascular risk [15]. However, two-thirds of individuals with hypertension are undiagnosed, untreated, or inadequately treated [16].

The delay in early diagnosis and/or treatment of hypertension leads to several complications such as strokes (CVA), coronary artery disease, and hypertensive kidney and heart diseases [17, 18]. These complications are among leading causes of death worldwide [19, 20]. By 2025, more than 125 million people with hypertension were expected in sub-Saharan Africa alone[13]. Arterial hypertension and other non-communicable diseases are expected to surpass infectious diseases as the leading causes of death by 2030[21], with serious socio-economic consequences due to premature deaths and healthcare expenditures.

Premature deaths ,productivity loss and healthcare costs related to the treatment of high blood pressure place a heavy burden on families [22] and push many of them into poverty [23, 24]. At the macroeconomic level, these high expenses and human losses have a significant impact on economic growth and reduce productivity [24-26]. Between 2011 and 2025, the cumulative loss in production due to non-communicable diseases, including high blood pressure, was expected to reach 7.28 trillion US dollars in low- and middle-income countries (LMICs), representing a loss of about 500 billion US dollars per year[27]. Cardiovascular diseases, including high blood pressure, account for nearly half of this cost [28]. Beyond these enormous costs, LMICs including Burundi, faces a major challenge of early diagnosis, timely treatment and control of high blood pressure [29, 30].

Despite implemented efforts on the NCD policy in Burundi, progress has been more limited on key indicators such as tobacco media campaigns, alcohol advertising restrictions, salt policies, and physical activity awareness[5]. A previous study conducted on 20 297 patients in rural areas of Burundi found hypertension as main CVD risk factors followed by diabetes and

alcohol abuse[31]. Effective hypertension control could prevent around 26,000 deaths by 2040[5]. However, the country lacks recent national surveys on hypertension and salt intake and does not have a functioning system for generating reliable cause-specific mortality data routinely.

Although Global Burden of Disease (GBD) studies provides independent estimates of the prevalence, mortality, and disability due to high blood pressure worldwide [32], studies aiming to understand the epidemiology of high blood pressure, its risk factors, and the medium and long term risk of cardiovascular morbidity in the in the context of Burundi are lacking, which has motivated the conduct of this study. Indeed, effective control of high blood pressure must involve a comprehensive prevention strategy at both the individual and population levels[20]. In addition to effective clinical interventions to delay the progression of high blood pressure toward cardiovascular complications, it is essential to have prognostic models that can identify patients at high risk of hypertension or cardiovascular morbidity[33]. This underscores the importance of the present study. This study aims to assess the extent of newly diagnosed high blood pressure and predict the risk of cardiovascular morbidity over a 10-year period among patients hospitalized in the internal medicine department of the Kamenge Teaching Hospital over a 5-year period. Specifically, this study aims to determine the prevalence of newly diagnosed and treated hypertensive patients, to identify associated factors to hypertension and to evaluate the cardiovascular disease morbidity risk on a 10-years horizon.

Evidence from this study could serve as a foundation for effective planning for Burundian NCD program, and formulate strategies to reduce hypertension and the associated cardiovascular morbidity. This study aligns with one the global objectives for non-communicable diseases, which aims to reduce the burden of high blood pressure by 33% by 2030 [34-38], the Global NCD Compact 2020–2030 aiming to accelerate progress on the prevention control and of NCD and Burundi NCD strategic plan.

2-0. Methods

2-1. Study design and sampling

We conducted a retrospective cross-sectional study at Kemenge Teaching Hospital. Retrospective data of patients admitted in internal medicine service between January 2018 and December 2022 were collected from their medical records using a semi-structured questionnaire. This period was targeted due the significant increase of CVDs incidence rate in Burundi since 2016[6]. **Figure 1** show the trend of cardiovascular diseases' incidence rate per 100 000 habitants between 2016 and 2022 in Burundi.

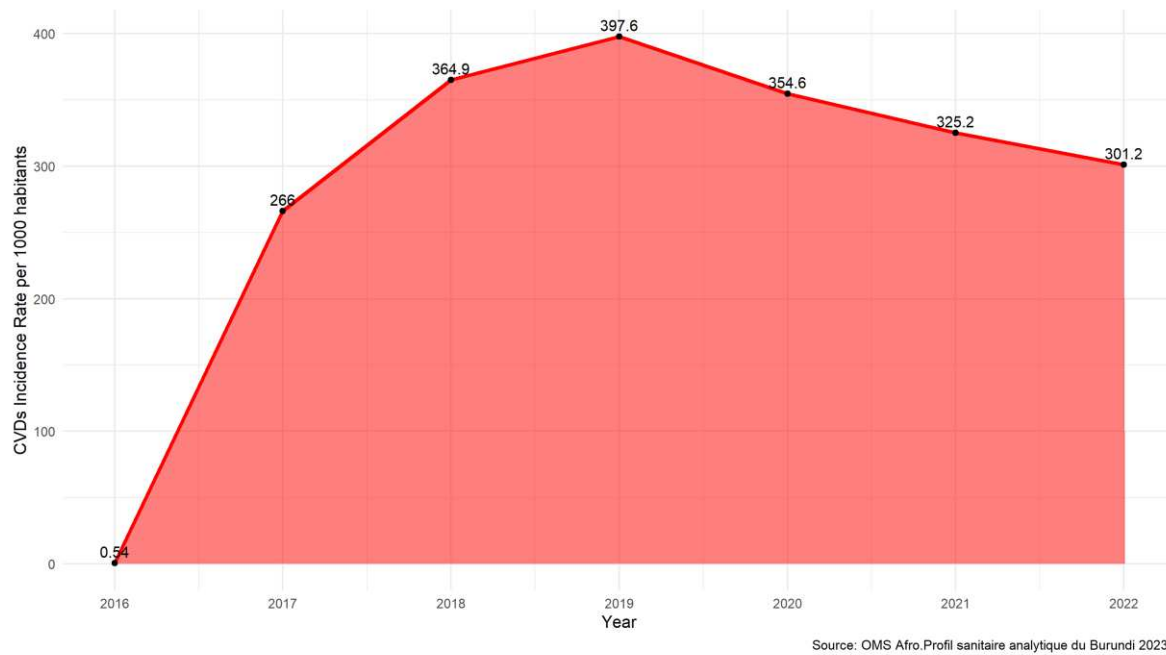


Figure 1. Incidence Rate of Cardiovascular Diseases per 100 000 habitants in Burundi

We included all patients admitted in internal medicine between January 2018 and December 2022 (Regardless of the reason for consultation and/or hospitalization) for whom all clinical and biological elements of the Framingham score were available on their medical records. Any patient with a known cardiovascular disease was excluded in this study. Additionally, the study excluded all patients with pre-existing hypertension, defined as those already receiving antihypertensive treatment prior to their admission to Kamenge Teaching Hospital. Indeed, patients not on treatment prior to admission were prioritized in this study, as uncontrolled hypertension places individuals at high risk for the development of cardiovascular disease. This risk is further compounded by the potential for cardiovascular morbidity associated with late-stage diagnosis, often occurring at the stage of complications. In this study, we considered the admission in the internal medicine of Kamenge Teaching Hospital to be independent (random) from one patient to another. Therefore, we used random sampling methods to include patients in the study. All patients in internal medicine service had the same chance to be selected. The minimal sample size was calculated as following:

$$n = \frac{\chi^2 \times p \times (1 - p) \times \pi}{\chi^2 \times (1 - p) + \alpha^2 \times (\pi - 1)} \quad (1)$$

Where χ^2 is the Chi square test (3.841) at 1 degree of freedom and 95% of confidence, π is population size (8960), n is the minimal sample size, p is the prevalence of hypertension and α , the error threshold (5%). Being unknown, the prevalence of hypertension was by default set at 0.5. The minimal sample size was 368 patients. A total of 714 patients met the criteria. In order to build a robust predictive model, all 714 patients were included in the study. Indeed, larger sample sizes enable the development of robust model able to guide healthcare decision-making.

2-4. Study and outcome variables

In this study, newly diagnosed hypertension is the variable of interest. It is defined as a systolic blood pressure greater than or equal to 140 mm Hg and/or a diastolic blood pressure greater than or equal to 90 mm Hg [39], with the diagnosis and initiation of antihypertensive treatment

for the first time during hospitalization in Kamenge Teaching Hospital [40]. Newly diagnosed hypertension was specifically considered for this study because hypertension is often identified at the stage of complications[17, 18]. Another reason is the high risk of cardiovascular morbidity and mortality associated with the untreated hypertension [41].

Potential factors for the high risk of hypertension and cardiovascular morbidity were selected based on their potential association and existing scientific evidence [42-45]. These factors include sex (male, female), place of residence (urban, rural), education level (primary or less, secondary, university), alcohol consumption (yes/no), tobacco use (yes/no), chronic kidney disease (yes/no), diabetes (yes/no), BMI, and family history of hypertension (yes/no). BMI was calculated by dividing weight in kilograms by the square of height in meters and categorized into four groups: underweight ($\text{BMI} < 18.5 \text{ kg/m}^2$), normal weight ($18.5 \text{ kg/m}^2 \leq \text{BMI} \leq 24.9 \text{ kg/m}^2$), overweight ($25.0 \text{ kg/m}^2 \leq \text{BMI} \leq 29.9 \text{ kg/m}^2$), and obesity ($\text{BMI} \geq 30 \text{ kg/m}^2$)[46]. In addition to the aforementioned factors, this study incorporated additional parameters from the Framingham Score (**Figure 2**), including systolic blood pressure (mm Hg), total cholesterol level (mmol/L), and high-density lipoprotein (HDL) cholesterol level (mmol/L). **Figure 2** illustrates the components of the overall risk score.

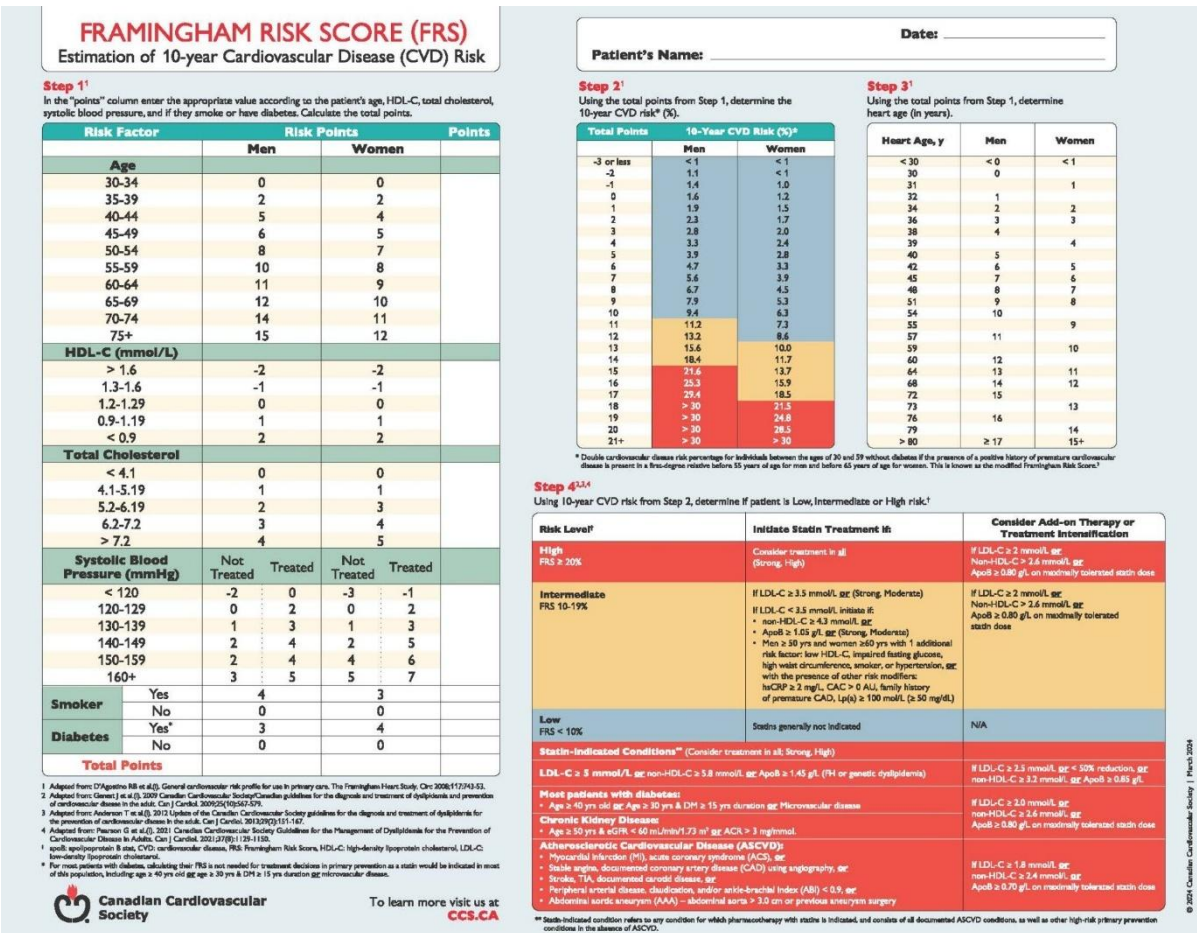


Figure 2: Framingham risk score

2-5. Data analysis

Data analysis was performed in several stages, including descriptive analysis, statistical modelling using the fixed-effects binary logistic model, evaluation of the predictive power of

the final model, and prediction of the probability of hypertension occurrence and the 10-year risk of cardiovascular disease (CVD). Descriptive analysis was conducted by presenting patient characteristics in the form of tables or graphs.

2-5-1. Bayesian belief update evidence based

Since some patients with newly diagnosed hypertension were excluded based on the Framingham score criteria requirements, the true prevalence of newly diagnosed hypertension for this study was estimated using Bayesian belief update evidence based methods[47]. Hypertension was a binomial outcome (either hypertensive or not hypertensive). We used $\beta eta(\alpha, \gamma)$ prior representing a uniform distribution, as well we have no prior knowledge about the prevalence at the national level $p \in [0,1]$. The likelihood function was Binomial distribution because we have a fixed sample size n and a number of successes (new hypertensive individuals). The posterior belief is $\beta eta(\tilde{\alpha}, \tilde{\gamma})$ where $\tilde{\alpha} = \alpha + x$ and $\tilde{\gamma} = \gamma + n - x$. The true prevalence was given by the following formula:

$$p(\theta/data) = \frac{p \times (data/\theta) \times p(\theta)}{p(data)} \quad (2)$$

Where θ is the true prevalence of hypertension and $data$, our data sample. The true prevalence is equivalent to the posterior mean:

$$Posterior\ mean = \frac{\alpha}{\alpha + \gamma} \rightarrow \frac{\tilde{\alpha}}{\tilde{\alpha} + \tilde{\gamma}} = \frac{\alpha + x}{\alpha + \gamma + x} \quad (3)$$

Using Bayesian updating, we combined the prior and likelihood to calculate the posterior $\beta eta(\alpha + x, \gamma + n - x)$, where x success of n trials is the evidence and posterior distribution of the prevalence p is binomial:

$$y \sim (n, p) \quad (4)$$

After running the Bayesian model, we sampled from the posterior distribution of p , posterior mean which give us an estimate of the true prevalence of hypertension in the population. We also checked the convergence using the Gelman-Rubin diagnostic[48].

2-5-2. Bayesian logistic regression

Univariate correlations were performed to assess the association between each predictor and the outcome variable and were further examined using univariate Bayesian logistic regression models. Bayesian logistic regression allowed incorporation of prior distributions for model parameters, providing a flexible framework for estimating uncertainty. Four Markov chain Monte Carlo (MCMC) chains, each with 4 000 iterations, were used to obtain posterior distributions. For each variable, we calculated the crude odds ratio (cOR) with its 95% credible interval. Variables associated with the outcome at $p < 0.20$ in the univariate analysis were entered into a multivariable Bayesian model, together with variables whose posterior probability do not exceed 0.25 and judged clinically relevant. The equation used to estimate risk in the Bayesian logistic regression model was as follow:

$$\pi_i = E(Y_i/X) = \frac{e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_n X_{in}}}{1 + e^{\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_n X_{in}}} \quad (5)$$

The Bayesian Logistic Regression with multiple predictors become as detailed below:

$$\text{logit}[\theta] = \text{logit}\left[\frac{\theta}{1-\theta}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon \quad (6)$$

where θ is the probability of hypertension occurrence, β_0 is the intercept, $\beta_1, \beta_2, \dots, \beta_n$ are the coefficients; and $X_1, X_2, \dots, X_n$ are the independent variables. Instead of estimating fixed values for the coefficients, we estimated their posterior distributions using prior distributions and observed data. From these models, we developed a multivariable model. Variable selection was guided by examination of the posterior coefficient distributions, with iterative updating to retain only predictors with meaningful posterior support. This selection was further informed by projection predictive variable selection, as described by Piironen, Paasiniemi, and Vehtari (2020)[49].

Bayesian Logistic regression was used because Markov chain Monte Carlo (MCMC) algorithms provide posterior distribution estimates without relying on large sample sizes, except for the number of iterations, which can be easily increased[50]. Additionally, Bayesian methods are more flexible, allowing the incorporation of external information through informative priors when available, or the use of noninformative priors. Adjusted odds ratios (aORs) with 95% credible intervals were reported for all predictors.

2-5-3. Model evaluation

Model fit was evaluated using leave-one-out cross-validation (LOO-CV) via the *loo* package, with moment matching applied for observations with high Pareto-k values. We examined calibration of the posterior and LOO predictive probabilities compared to observed binned event rates. We sorted the predicted probabilities in ascending order, bin the corresponding binary observations and plotted the mean and uncertainty interval based on binomial distribution. We also used the new approach for assessing calibration (or reliability as they call it) that uses nonparametric isotonic regression and the pool-adjacent-violators (PAV) algorithm to estimate conditional event probabilities (CEPs) with automated choice of bins[51].

2-5-4. Evaluation of the 10-year cardiovascular risk

The cardiovascular risk morbidity was assessed using the Canadian Framingham Risk score, which is an effective tool for evaluating the 10-year risk of cardiovascular diseases[52]. The Framingham score is based on the individual's sex, tobacco use, high-density lipoprotein cholesterol level (in mmol/l), systolic blood pressure (in mm Hg), total cholesterol level (in mmol/l), diabetes, age, and antihypertensive treatment. This score predicts cardiovascular morbidity over a 10-year period. We evaluated the 10-year cardiovascular morbidity risk in both newly and non-newly diagnosed hypertensive patients, meaning all 714 patients included in the study. This evaluation was based on all the elements of the Framingham score and was subsequently categorized into three risk levels. A comparative analysis was conducted between hypertensive and non-hypertensive patients. The data processing and analysis for this study were carried out using dplyr, ggplot, rstanarm package and R Studio version 3.5.0 [53].

2-6. Ethical considerations

For the conduct of this study, we received a research authorization granted by the General Direction of CHU Kamenge (**Ref: 2023DGCHUK.835/11.5**). This authorization provided us access to the medical records of the patients. The data were collected from these medical

records. To ensure patient anonymity, identifying information was anonymized and replaced with unique codes.

3-0. Results

3-1. Socio-demographic characteristics of patients

In this study, the median age of patients was 43(95% CI :42, 44) years. The average age was 59.8 (95% CI: 56.1-61.9) and 43.8(95% CI: 39.6- 42.4) respectively for newly diagnosed hypertensive and treated patients, and no hypertensive patients (**Figure 3**). **Figure 3** shows the age-specific distributions of hypertension (A) and cardiovascular disease risk (B)

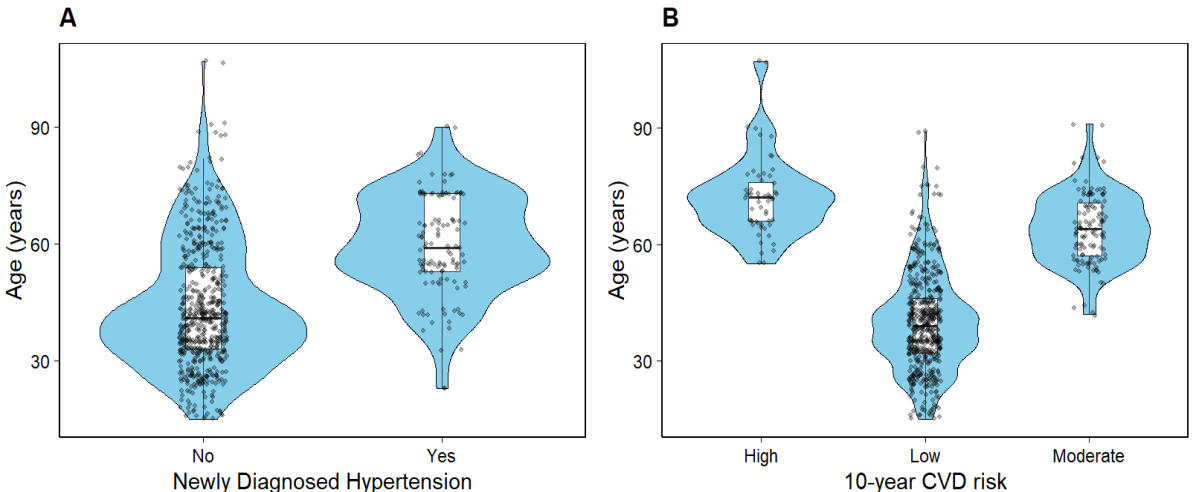


Figure 3. Age-specific distributions of hypertension (A) and cardiovascular disease risk (B)

The male sex was observed in 57.98% of the cases, resulting in a sex ratio of 1.38. Nearly two-thirds of the patients (60.9%) were more than 40 years old (**Table 1**). The majority of the patients had secondary-level education (46.8%), were married (74.5%), and live in Urban areas (53.4%). **Table 1** shows the characteristics of the patients.

Table 1. Socio-demographic characteristics of patients

Characteristics	Total N=714	%	Newly diagnosed hypertensive				p ^{HTA+} %
			HTA-	%	HTA+	(%)	
Sex							
Female	300	42.1	246	34.5	54	18.0	13.4
Male	414	57.9	348	48.7	66	15.9	11.9
Age (in years)							
				0.0			
15-39	280	39.2	274	38.4	6	2.1	1.6
40-59	263	36.8	207	29.0	56	21.3	15.9
≥60	171	23.9	113	15.8	58	33.9	25.3
Education level							
Primary or less	276	38.7	247	34.6	29	10.5	7.9
Secondary	334	46.8	273	38.2	61	18.3	13.6
University	104	14.6	74	10.4	30	28.9	21.5
Marital status							
Maried	532	74.5	429	60.1	103	19.4	14.5
Unmarried	182	25.5	165	23.1	17	9.3	6.9

Residence							
Rural	333	46.6	277	38.8	56	16.8	12.6
Urban	381	53.4	317	44.4	64	16.8	12.5
Alcohol							
No	350	49.1	294	41.2	56	16.0	11.9
Yes	364	50.9	300	42.0	64	17.6	13.1
Tobacco							
No	657	92.1	554	77.6	103	15.7	11.7
Yes	57	7.9	40	5.6	17	29.8	22.2
CKF							
No	342	47.9	332	46.5	10	2.9	2.2
Yes	372	52.1	262	36.7	110	29.6	22.1
Diabetes							
No	553	77.5	499	69.9	54	9.8	7.3
Yes	161	22.5	95	13.3	66	41.0	30.6
Hypertension in family							
No	344	48.2	334	46.8	10	2.9	2.2
Yes	370	51.8	260	36.4	110	29.7	22.2
BMI							
Normal	544	76.2	474	66.4	70	12.9	9.6
Overweight	122	17.1	90	12.6	32	26.2	19.6
Obesity	48	6.7	30	4.2	18	37.5	28.0

CKF: Chronic Kidney Failure, BMI: Body Mass Index, pHTA⁺: proportion of newly hypertensive patients

Of the 714 patients included in this study, 120 had a recently diagnosed hypertension, representing a proportion of 16.81% in our sample. The posterior distribution (Posterior mean) of the prevalence parameter yielded a mean estimate of 16.9% (95% CrI: 14.2%–19.7%), as shown in **Figure 4**. Gelman-Rubin diagnostic showed the potential scale reduction factor for the MCMC and its upper bound of the 95% credible interval to be respectively 1 and 1.01. This suggests the absence of divergence, a well-mixage in the chains, and MCMC sampling convergence. **Figure 4** shows the prevalence and density of newly diagnosed hypertension.

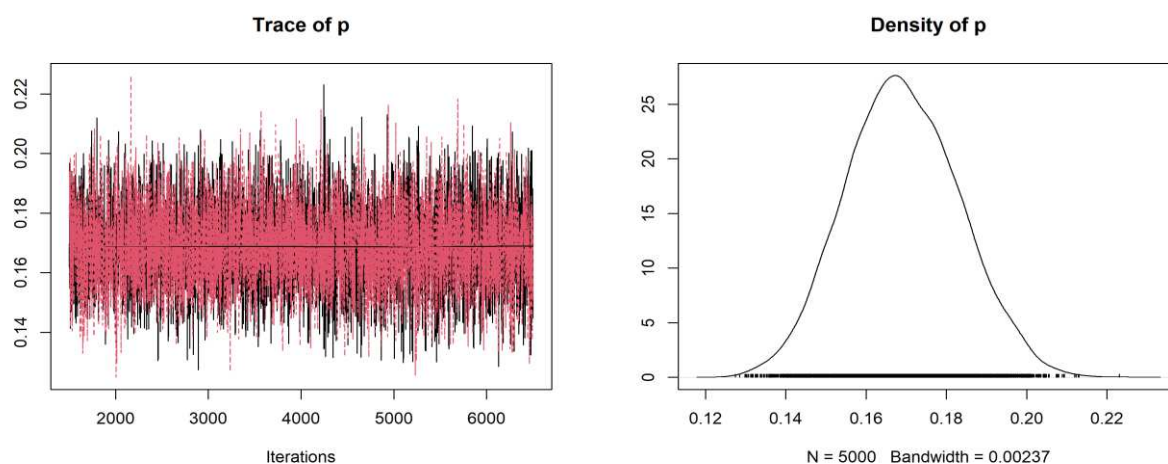


Figure 4. Prevalence and density of newly diagnosed hypertension

The prevalence of newly diagnosed hypertension in men and women is 15.94% and 18.0%, respectively. However, this difference between the sexes is not statistically significant ($p = 0.532$). Higher proportions, above the overall prevalence, were observed in female patients (18%), married patients (19.36%), those with a secondary (18.26%) or university (28.85%) level of education, patients aged 40 to 59 years (21.29%) or aged 60 years and older (33.92%). In contrast, the lowest prevalence (2.14%) was observed in individuals under 40 years old.

The majority of patients consumed alcohol (50.98%), were non-smokers (92.02%), had a history of chronic kidney disease (52.10%), were non-diabetic (77.45%), had a family history of newly diagnosed (51.82%), and had a normal body mass index (76.19%). Newly diagnosed was more commonly observed in overweight patients (26.2%), obese patients (37.5%), those with chronic kidney disease (29.6%), and alcohol drinkers (17.6%). **Table 2** shows the distribution of patients according to the Framingham score parameters.

Table 2. Distribution of patients according to the Canadian FSR parameters

Parameters	Total patients		Newly diagnosed hypertensive				P _{HTA+} (%)
	N=714	%	HTA-	(%)	HTA+	(%)	
<i>SBP (in mm Hg)</i>							
< 120	324	45.38	310	43.4	14	4.32	3.23
120 - 129	111	15.55	97	13.6	14	12.61	9.42
130 - 139	114	15.97	108	15.1	6	5.26	3.93
140 - 149	55	7.70	35	4.9	20	36.36	27.15
150 - 159	47	6.58	20	2.8	27	57.45	42.90
≥160	63	8.82	24	3.4	39	61.90	46.22
<i>Total cholesterol</i>							
<4.1	323	45.24	264	37.0	59	18.27	13.64
4.1 - 5.19	230	32.21	191	26.8	39	16.96	12.66
5.2 - 6.19	157	21.99	135	18.9	22	14.01	10.46
>7.2	4	0.56	4	0.6	0	-	-
<i>HDL cholesterol</i>							
<0.9	128	17.93	96	13.4	32	25.00	18.67
0.9 - 1.19	126	17.65	107	15.0	19	15.08	11.26
1.2 - 1.29	129	18.07	115	16.1	14	10.85	8.10
1.3 - 1.60	176	24.65	137	19.2	39	22.16	16.55
>1.60	155	21.71	139	19.5	16	10.32	7.71
<i>Age (in years)</i>							
≤34	218	30.53	214	30.0	4	1.83	1.37
35-39	62	8.68	60	8.4	2	3.23	2.41
40 - 44	98	13.73	86	12.0	12	12.24	9.14
45-49	54	7.56	52	7.3	2	3.70	2.76
50 - 54	55	7.70	37	5.2	18	32.73	24.44
55 - 59	56	7.84	32	4.5	24	42.86	32.00
60 - 64	49	6.86	39	5.5	10	20.41	15.24
65 - 69	40	5.60	26	3.6	14	35.00	26.13
70 - 74	50	7.00	26	3.6	24	48.00	35.84
≥75	32	4.48	22	3.1	10	31.25	23.33

SBP : Systolic Blood Pressure

More than half of the patients with a SBP greater than 150 mm Hg at admission were already hypertensive (**Table 2**). Only 18.27% had a total cholesterol level lower than 4.1 g/l. Nearly a quarter of the patients had low levels of high-density lipoprotein (HDL) cholesterol. Low proportions (<5%) of hypertensive patients were observed among those under 40 years of age.

3.2. Factors associated with newly diagnosed

Factors associated with newly diagnosed were assessed using univariates and multivariate Bayesian logistic regressions. **Table 3** shows the crude and adjusted odds ratios and their 95% credible interval both levels of Bayesian logistic regressions.

Tableau 3. Univariate and multivariate Bayesian logistic regression models

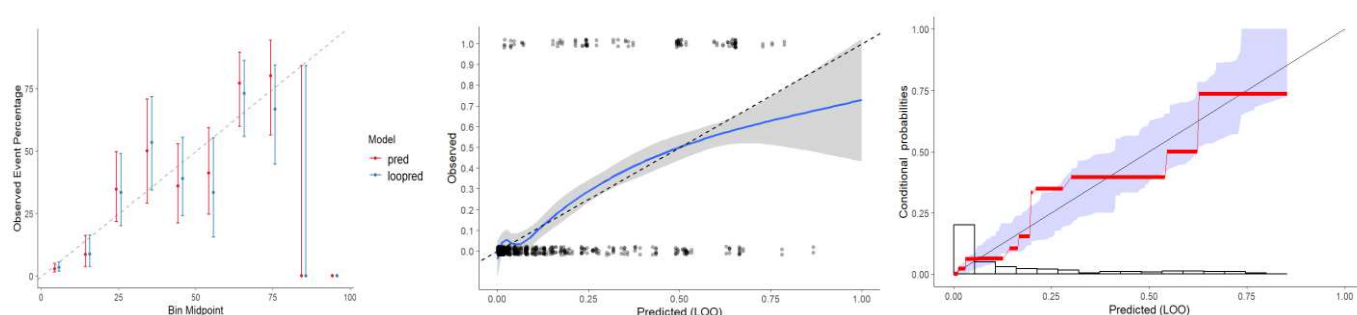
Characteristics	Univariate		Multivariate	
	cOR	CrI (l-95%, u-95%)	aOR	CrI (l-95%, u-95%)
Age (in years)				
]15-40]	Ref.		Ref.	
]40-59]	13.07	[5.85,33.62]	6.49	[2.65,13.26]
≥60	25.03	[10.88,64.23]	25.94	[9.77,54.86]
Sex				
Female	Ref.		Ref.	
Male	0.87	[0.58,1.29]	0.71	[0.43,1.08]
Education level				
Primary or less	Ref.		Ref.	
Secondary	1.92	[1.20,3.11]	4.68	[2.65,7.54]
University	3.46	[1.95,6.18]	10.17	[4.80,18.54]
Marital status				
Unmarried	Ref.		Ref.	
Married	2.39	[1.40,4.22]	2.68	[1.22,4.98]
Residence				
Rural	Ref.		Ref.	
Urban	1.00	[0.67,1.48]	0.94	[0.56,1.42]
Alcohol consumption				
No	Ref.		Ref.	
Yes	1.12	[0.76,1.67]	1.05	[0.66,1.57]
Tabacco consumption				
No	Ref.		Ref.	
Yes	2.25	[1.20,4.11]	3.74	[1.64,6.99]
Diabetes				
No	Ref.		Ref.	
Yes	6.42	[4.22,9.86]	1.64	[0.96,2.59]
Body mass index				
Normal	Ref.		Ref.	
Overweight	2.39	[1.48,3.84]	2.19	[1.22,3.53]
Obesity	4.01	[2.10,7.62]	4.42	[2.02,8.23]
Chronic kidney failure				
No	Ref.		Ref.	
Yes	14.30	[7.62,29.38]	6.58	[3.22, 11.83]
Hypertension in family				
No	Ref.		-	-

Yes	14.59	[7.71,29.80]	-	-
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The education level, diabetes, advanced age, obesity, overweight, marital status, chronic kidney failure, and family history of hypertension are significantly associated with newly diagnosed hypertension (**Table 3**).

3-3. Model comparison using leave-one-out cross-validation (LOO).

We evaluated predictive performance using approximate leave-one-out cross-validation. The main model showed good overall fit (posterior classification accuracy=0.86), with an estimated expected log predictive density (elpd_loo) at -226.1 (SE = 15.6) and all Pareto k estimates < 0.7, indicating reliable LOO estimates (**Figure 5**). In contrast, the intercept-only baseline model performed was substantially worse (elpd_loo = -324.3 , SE = 16.1). Direct comparison using loo compare demonstrated a large and statistically decisive improvement in predictive accuracy for the full model: Δ elpd = 98.2 (SE = 13.8) in favor of the main model. This difference corresponds to more than seven standard errors, providing strong evidence that the predictors included in the full model meaningfully improve out-of-sample prediction relative to the baseline. **Figure 5** shows the model calibration.



A. Mean and uncertainty interval

B. Narrower uncertainties

C. Estimates of conditional probabilities

3-4. LEVEL OF 10-YEARS CARDIOVASCULAR DISEASES RISK

The level of 10-years cardiovascular diseases risk was assessed in both type of patients (hypertensive and non-hypertensive). **Figure 6** shows the level of Cardiovascular Diseases Morbidity Risk among hypertensive and un hypertensive patients.

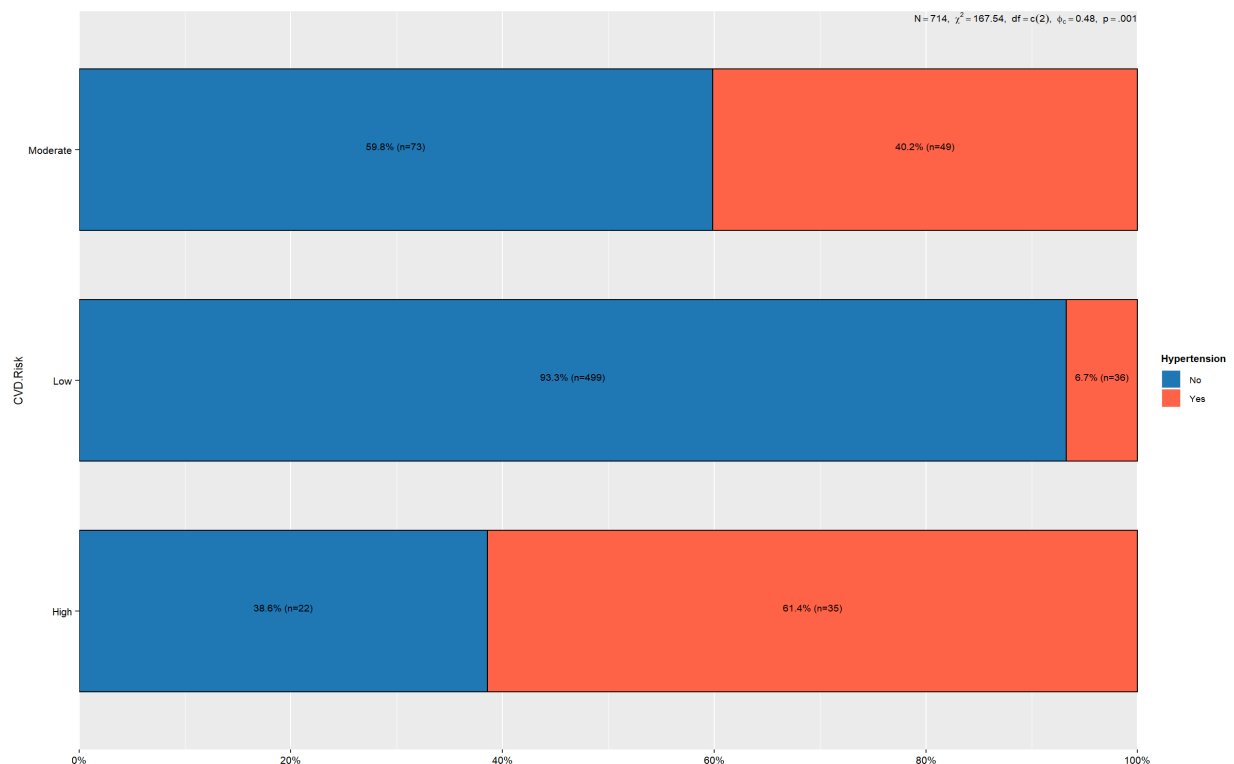


Figure 6. Risk of cardiovascular diseases in hypertensive and non-hypertensive patients

A quarter of patients (25.1%) have at least a moderate risk of cardiovascular morbidity within the next ten years (**Figure 6**). Near a half (41.2%) of patients with moderate cardiovascular risk were those with a newly diagnosed hypertension. Among patients with high 10-year cardiovascular risk, more than two third (61.4%) are those also newly diagnosed hypertensives. The majority of patients with low 10-year cardiovascular risk (93.3%) are not hypertensive. The newly diagnosed hypertension is significantly associated with the 10-year cardiovascular risk ($p<0.05$). **Figure 7** shows the correlation between DBP and 10-year cardiovascular diseases risk among in non-hypertensive and hypertensive patients.

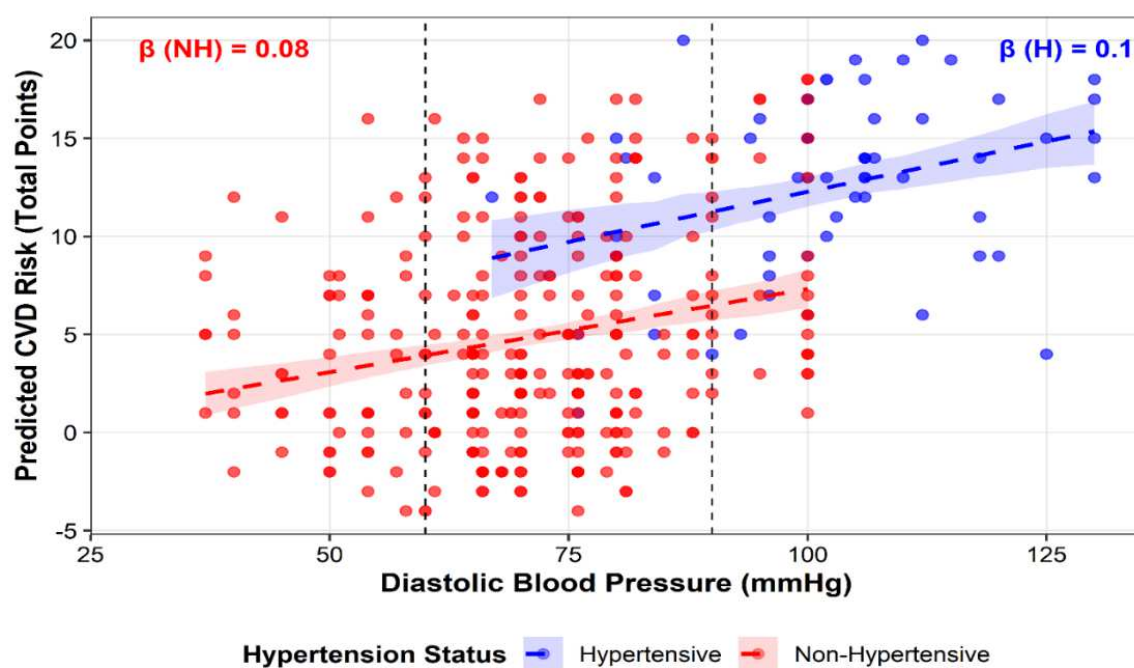


Figure 7. DBP and 10-year CVD risk correlation in non-hypertensive and hypertensive patients. A positive association between DBP and predicted CVD risk across both hypertensive and non-hypertensive individuals was observed (**Figure 7**). As DBP increases, predicted CVD risk rises for both groups; however, this relationship is stronger among hypertensive participants ($\beta = 0.10$) compared to non-hypertensive individuals ($\beta = 0.08$). At equivalent blood pressure levels, hypertensive individuals exhibit higher predicted CVD risk scores, suggesting that hypertension status independently amplifies CVD risk beyond the effect of blood pressure alone. **Figure 8** shows the distribution of CVD level in hypertensive and non-hypertensive patients.

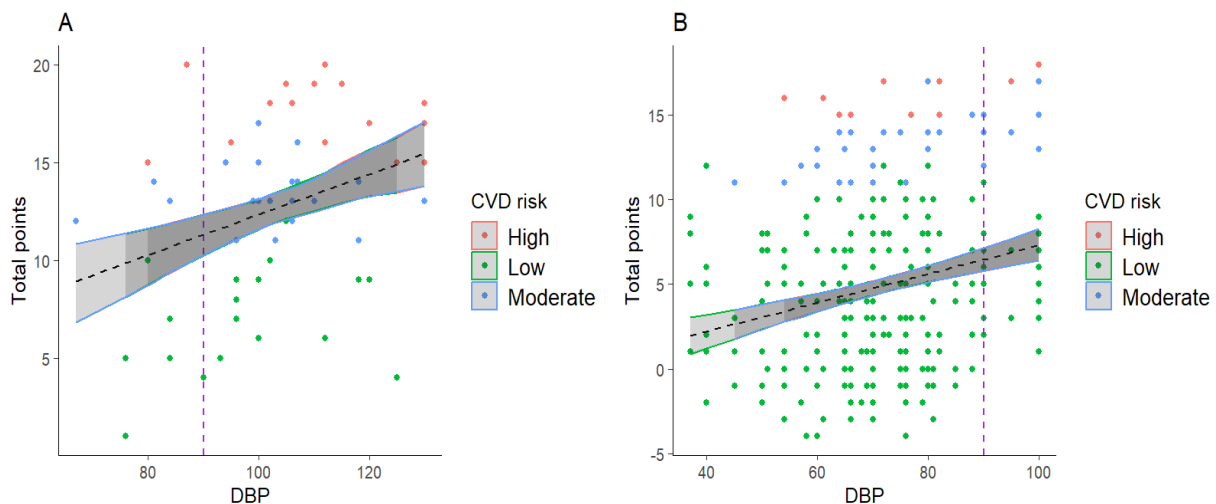


Figure 8. Distribution of CVD risk in hypertensive (A) and non-hypertensive (B) patients

High CVD risk is more distributed in patients with a DBP greater than the threshold (90 mmHg) (**Figure 8.A**). A low risk of 10-year CVD is more observed among patients with DBP less than the threshold (90 mmHg) (**Figure 8.B**).

4. Discussion

Arterial hypertension and cardiovascular diseases remain major public-health challenges in Burundi. Using a Bayesian belief update evidence-based method, Bayesian logistic regression, and the Framingham Risk Score (FRS), this study estimated the prevalence of newly diagnosed hypertension, identified associated factors, and assessed 10-year CVD risk.

The prevalence of newly diagnosed hypertension was 16.9% (95% CrI 14.2–19.7), a finding consistent with evidence from Benin (15.2%)[54], observations from China (23%)[55], and from Mexico and the United States (24.1%)[56, 57]. In contrast, it is lower than estimates (50%) reported in some recent studies conducted in Africa [58], as well as those observed in Chinese adults over 15 years (28.56%)[59]. The exclusion of known hypertensive individuals before admission and those with incomplete FRS data may partially explain the comparatively lower prevalence. The estimated prevalence is also below the regional average reported for sub-Saharan Africa, possibly due to differences in study populations and sample sizes[60].

Hypertension prevalence in our study was higher among women than men, consistent with findings from Saudi Arabia showing women suffering from hypertension than men over the last three decades [61], and others from Lesotho, and Sudan showing a higher prevalence in women than in men[62, 63]. However, as in Benin and Sweden, the difference between sexes showed a slight female predominance without a statistical significance[54, 64]. The higher

prevalence among women might reflect post-menopausal hormonal changes, including oestrogen deficiency, arterial wall thickening, and increased arterial stiffness, which have been linked to elevated blood pressure[65, 66].

The highest prevalence of newly diagnosed hypertension was among individuals with diabetes, whereas the lowest prevalence was in adults younger than 40 years. These findings mirror those from studies in Sudan, Côte d'Ivoire, and Ghana, where younger individuals exhibit lower hypertension prevalence [63, 67-70]. They are also consistent with findings from a multicentre study conducted on patients with type 2 diabetes in Ethiopia showing a high prevalence of newly diagnosed hypertension (61%) among diabetics[71]. The strong association between diabetes and hypertension reflects shared risk pathways including physical inactivity and obesity suggesting a bidirectional risk cycle[72].

After adjustment using Bayesian logistic regression tobacco consumption, advanced age, higher education level, overweight and obesity, and history of hypertension were significantly associated with hypertension. Similar associations of hypertension and overweight, smoking, education level, and advanced age have been reported in Kenya and Bangladesh[73, 74]. A recent study in Western Uganda, using the 2017 ACC/AHA guidelines, found also age ≥ 40 years, overweight, and obesity to be predictors of hypertension [75].

The strong association between advanced age and hypertension is in line with biological mechanisms involving progressive arterial resistance and vascular remodeling [76]. Although no sex association was found, the literature suggests that hormonal changes around the age of 45 may increase women's susceptibility to hypertension[77]. The progressive deficiency in oestrogen after menopause could lead to thickening of the arterial wall and increase in the tone of muscle fibres, resulting in greater arterial stiffness and hypertension[65, 66].

In contrast to studies from Brazil and Ghana showing a high risk of hypertension in married women, marital status was not associated with hypertension[78, 79]. In some studies, the literature on marital status and hypertension is inconclusive [62]. Our study did not show an association between marital status and hypertension. These results are contrary to those of other studies, where married women had a significantly higher risk of hypertension[78]. These results are also contrary to those previously reported in Brazil regarding this association[79]. In some studies, the literature on marital status and hypertension is inconclusive [62].

Alcohol consumption also showed no association with hypertension, consistent with findings from Nepal and parts of Europe [80], though contrary to recent reports from India showing alcohol consumption to be a significant risk factor for hypertension[81, 82]. The lack of association may reflect cultural tendencies to underreport lifestyle behaviours on alcohol in Burundi and the absence of alcohol-intake quantification in our dataset. Pathophysiological evidence indicates that alcohol consumption can elevate blood pressure through sympathetic activation and dysregulation of renin-angiotensin-aldosterone system[83].

The 10-year CVD risk was present in 25.1% of participants, of whom 30% had high risk. This proportion is lower than estimates from specific high-risk groups in Belgium, such as patients with sleep apnoea, where moderate-to-severe risk reaches nearly 60% [84]. Most individuals with low 10-year risk were normotensive, whereas hypertension was present in over one-third of individuals with moderate risk and in more than half of those with high risk. These findings are consistent with recent studies conducted in showing hypertension as main cardiovascular

risk factor[85]. The observed high-risk of CVD morbidity in hypertensive patients can be due to the late diagnosis, probably at complication stage.

DBP was positively correlated to the cardiovascular risk in both non-hypertensive and hypertensive patients. High CVD risk was more distributed in patients with a DBP greater than the threshold (90 mmHg). These are consistent with recent observational investigations and clinical trials which showed the cardiovascular disease in humans to be primarily caused by a right-sided shift in the distribution of DBP[86].

This study offers several strengths. First, application of Bayesian methods to a large sample enables robust estimation. Second, the combined use of hypertension prevalence estimation, risk-factor modelling, and long-term CVD risk assessment provides an important insights on cardiovascular diseases risk in Burundi. Although the dataset is, to some extent, not nationally representative, the Kamenge Teaching hospital serves patients from across the country, and Bayesian estimation, particularly the Bayesian belief update evidence-based method, improves inference regarding the prevalence.

Despite these strengths, it is important to note some limitations. First, this study is a cross-sectional study using secondary data. Key lifestyle variables, including quantity and type of alcohol or tobacco consumed and physical activity were unavailable while they are well known to be associated with hypertension. Caution should be taken when generalizing the results from a single-center on hypertension in Burundi. To validate the results, future multicentre studies should incorporate additional biomarkers and develop country-specific CVD risk models and well calibrated to Burundian population. Moreover, methods such as Hidden Markov Models may offer valuable insights into transitions between CVD risk levels[87].

Importantly, findings from this study underscore the need to integrate mechanistic insights into future cardiovascular research in Burundi. Inflammatory mechanisms including NLRP3 inflammasome activation and gasdermin-D-mediated pyroptosis are increasingly recognised as key drivers of cardiovascular pathology[88]. Future research in Burundi could integrate these biological pathways with risk modeling to inform precision prevention and innovative therapeutic strategies. Potential therapeutic approaches for cardiovascular risk reduction and lipid metabolism regulation should also be explored[89].

5. Policy implications

Hypertension and cardiovascular diseases are major and growing public health concerns in Burundi, requiring urgent policy attention. The burden of newly diagnosed hypertension in this study underscores the need to strengthen routine blood pressure screening, especially among high-risk groups such as older adults, women, and individuals with diabetes or obesity. Integrating cardiovascular risk assessment tools into national guidelines and primary care could improve early detection and treatment. Public-health policies should also prioritize prevention through population-level interventions that reduce tobacco use, promote healthy diets, and encourage physical activity, while embedding hypertension management within broader non-communicable disease control programmes. Strengthening health-information systems and investing in nationally representative research will be essential to tailor evidence-based interventions and to support sustained reductions in the burden of cardiovascular disease, consistent with national priorities and the 2030 Agenda for Sustainable Development.

6. Conclusions

This study reveals a burden of newly diagnosed hypertension among hospitalized patients at Kamenge Teaching Hospital, with significant associations with age, education, obesity, tobacco use, and family history of hypertension. A considerable proportion of patients exhibits moderate to high 10-year cardiovascular disease risk according to the Framingham Risk Score, underscoring the substantial but often unrecognised burden of cardiovascular morbidity in the country. The use of Bayesian methods provided robust estimates of prevalence and key risk factors that can inform targeted interventions. These findings highlight the urgent need for systematic blood pressure screening, early diagnosis, and integrated risk-management strategies to mitigate the growing impact of hypertension and cardiovascular diseases in Burundi.

Declarations

Clinical trial number

Not applicable.

Authors' contributions

AI conceptualized the study and designed the methodology. CI conducted the preliminary analysis. CI and AI jointly curated the analysis. RT, POC, ADA, and AK contributed to the intellectual content. ENO, EN and EB supervised the work and reviewed the subsequent versions. All authors approved the final manuscript for publication. AI agreed to handle all correspondence related to the intellectual content of the study and serves as the corresponding author.

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Data availability

The dataset related to this study is available with the corresponding author and can be available on reasonable request.

Ethics approval and consent to participate

The study was approved by an institutional ethics committee of Kamenge Teaching Hospital (N/Ref.2023/DGCHUK837/11.5). No informed consent was needed. All data were fully anonymized before we accessed them. The study was conducted by the guidelines of the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

Acknowledgement

The authors declare no competing interests

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7.List of Abbreviations and Acronyms

Abbreviation and Acronyms	Full meaning
%	Percentage
ACC	American College of Cardiology
AHA	American Heart Association
GBD	Global Burden Disease
HDL	High Density Lipoprotein
HTA	Hypertension
HTA-	Non-hypertensive patients
HTA+	Hypertensive patient
CrI	Credible interval
LDL	Low Density Lipoprotein
CVD	Cardiovascular Diseases
WHO	World Health Organization
OR	Odds ratio
aOR	Adjusted Odds ratio
cOR	Crude Odds ratio
p ^{HTA+}	Prevalence of Hypertension

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