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IMPACT OF ANTIHYPERTENSIVE DRUG ADHERENCE ON LONG-TERM CARDIOVASCULAR OUTCOMES: A PREVENTIVE MEDICINE PERSPECTIVE

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Abstract

The long-term cardiovascular outcomes strongly depend on the adherence to antihypertensive medication, which is still a common global issue that is not eliminated. This was a preventive-medicine trial that tested the relationship between the level of adherence and the occurrence of major cardiovascular events by a mixed-method design by combining quantitative clinical indicators, medication-possession ratios, the tracking of long-term outcomes, and qualitative measurement of behavioral barriers. A total cohort of hypertensive adults was assessed on high-, medium-, and low-adherence levels, and the concept of adherence was measured by means of the Medication Possession Ratio (MPR) and self-reports scales. Monitored cardiovascular outcomes, such as myocardial infarction, stroke, heart failure hospitalization, and cardiovascular mortality, were followed up over a multi-year follow-up period. Findings revealed that excellent compliance was closely linked to better blood pressure management, reduced LDL-C and fasting glucose, reduced acute cardiovascular, and significantly less mortality in the long term. On the contrary, low-adherence patients reported a much higher event rate, worse metabolic and hemodynamic status, and risk and responses in predictive modeling. A qualitative analysis of the data conducted revealed forgetfulness, medication fatigue, financial strain, and low perceived necessity as the key contributors to non-adherence. Combining clinical data with behavioral and predictive data proved that adherence is a modifiable and independent predictive variable of cardiovascular outcomes. These data support the importance of adherence-strengthening measures, such as patient education, electronic reminder tools, and simplified regimens as a solution to decrease cardiovascular morbidity and mortality that can be prevented. In general, the paper has made it clear that the optimization of the adherence to antihypertensives is one of the most effective preventive measures existing in contemporary cardiovascular medicine.

INTRODUCTION

Hypertension, a disease which has afflicted approximately half of the adult population of the United States, has very dramatic role to play in causing cardiovascular diseases as well as stroke. It is due to this reason that proper treatment plans are essential (Lee et al., 2024). Having the effective antihypertensive drugs available many high blood pressure victims undergoing treatments are struggling to achieve good management of blood pressure. According to the international literature, half to two-thirds of this group of patients still have not reached their desired blood pressure levels (Kim et al., 2025). The persistent mismatch of the proposed and actual blood pressure control indicates that the population has a severe health problem since untreated hypertension is one of the leading causes of premature deaths in countries the world over (Nyirakabera & Gbadamos, 2024) (Choudhry et al., 2021). Non-adherence to antihypertensive medication is a very critical (yet, frequently underrated) reason of poor blood pressure management. It affects the patient outcomes significantly and puts a strain on health facilities (Gardezi et al., 2023). This is worsened by the fact that high blood pressure is in most cases not symptomatic. It can lead to the reduction of the readiness of patients to take medication on a regular basis (Gardezi et al., 2023; Hamrahian et al., 2022). In fact, non-adherence to medications is a complicated phenomenon, the development of which is affected by a great number of factors. They are the socioeconomic position, structure of the healthcare system, type of prescribed treatment, and patient characteristics. All these concerns are a tremendous impediment to the ideal range of blood pressure control, which may be proven through the papers of Lee et al. (2024) and Choudhry et al. (2021). This gap, together with the risk of jeopardizing the health of individual patients, creates a considerable load on the healthcare system on the international scale, and this is why the opportunity to know the factors influencing their compliance in detail and formulate the effective intervention strategies is significant (Robberechts et al., 2024; Choudhry et al., 2021). Low compliance with antihypertensive drugs is a deterrent to good blood pressure control that has been well documented. In addition, it is also associated by itself with an increased risk of adverse cardiovascular outcomes (Georgianos et al., 2024; Kim et al., 2025). Ineffective compliance with treatment plans is directly associated with the aggravation of illnesses, unnecessary hospitalization, increased health rates, and increased mortality (Commodore-Mensah et al., 2023). Although there is a general awareness that hypertension is a significant risk factor, which can be altered, this problem has a significant impact on the global cardiovascular disease burden and associated mortality (Hamrahian et al., 2022). Moreover, the rate of high blood pressure in the world remains high with the lowest- and middle-income nations having low levels of awareness, treatment, and control of the condition (Shiraly et al., 2022). Globally, 10.8 million deaths are caused by the failure to control blood pressure (Pathak et al., 2021). This alarming figure shows that there is an urgent need to manage the variables which contribute to blood pressure poor control. A significant, yet frequently neglected, risk factor, which can be modified, is medication non-adherence (Hamrahian et al., 2022). Consequently, it is essential to identify and decrease both intentional and accidental nonadherence to enhance the treatment outcomes and decrease the overall health problems affecting the population in terms of uncontrolled hypertension (Pathak et al., 2021; Mancia et al., 2023). Thus, efficient methods of enhancing adherence are highly valued, bearing in mind that the existing measures to manage hypertension in the world are hindered by challenges such as lack of information,

unwillingness to switch treatments, and poor adherence to drugs (Pathak et al., 2021). This discussion is a critical analysis of the diverse implications of adhering to antihypertensive drugs on the long-term cardiovascular disease, with a focus on preventive medicine perspective. The given analysis concentrates on the clinical implications of non-adherence and makes a distinction between real and apparent resistant hypertension as well as explores patient-centered approaches that can help improve drug adherence (Hamrahian et al., 2022). Moreover, the research puts an essential emphasis on the role of communication between medical practitioners and patient engagement in adherence promotion, and the end-goal is to decrease the cardiovascular disease load (Hamrahian et al., 2022). The failure to adhere to prescribed antihypertensive medications is an important element in the inability to control blood pressure and increase the chances of condition-related outcomes linked to hypertension, including stroke, ischemic heart disease, and chronic kidney disease (Aminde et al., 2024). The given analysis also highlights the need to engage patients in the dialogue and doctors who are able to communicate with no judgment when tackling this problem. Such strategies may result in the enhanced control of blood pressure and the increase in health outcomes (Hamrahian et al., 2022).

METHODOLOGY

The current study used a mixed-methods preventive-medicine model, which included quantitative evaluation of the adherence, longitudinal surveillance of the cardiovascular events and qualitative studies of the behavioral barriers. The methodology of the study was made in such a way that it would help to assess the influence of adherence to antihypertensive treatment on the changes in the risks of cardiovascular in the long term. They were recruited in outpatient hypertension clinics. Stratified sampling ensured the sample would be representative of various ages, sexes as well as the duration of the condition. We measured adherence through two procedures, the consistency of prescription refilling and Medication Adherence Rating Scale (MARS). This enabled us to assess the behavioral compliance as well as objective trends in the acquisition of drugs. The Medication Possession Ratio (MPR) was used to assess medication possession and was adopted by using the following formula:

$$\text{MPR} = \frac{\text{Total Days' Supply Obtained}}{\text{Days in Evaluation Period}} \times 100.$$

We were evaluating clinical and biochemical factors at the beginning and during annual follow-ups. These were systolic and diastolic blood pressure, total cholesterol, LDL-C, HbA1c, BMI and high sensitivity CRP. A ten-year follow-up on cardiovascular outcomes was accomplished by use of a surveillance system based on electronic records. These results were heart attacks and strokes, heart failure hospitalization, and cardiovascular deaths. The Cox proportional-hazards regression model was utilized to determine the risk of an event happening over time and this could be written mathematically as:

$$h(t) = h_0(t)\exp(\beta_1 A + \beta_2 X_2 + \ldots + \beta_n X_n),$$

In this model, AAA refers to the level of compliance and XXX incorporates such factors as age, smoking, diabetes, lipid issues, and the initial severity of the hypertension.

The obstacles, including forgetfulness, medication exhaustion, economic hardships, side effects, and the lack of awareness of the symptoms, were examined with the help of the qualitative data that was collected

with semi-structured interviews with a subset of the participants. These obstacles were categorized using thematic analysis and then the categories were juxtaposed to the quantitative data. The combination of the two datasets was done by convergent analytical model. Quantitative relations between adherence and outcomes and patient-reported behavioral characteristics were compared using this model. This was aimed at developing an all-inclusive preventive-medicine risk architecture. The entire process, starting with the recruitment of the participants up to the integrated modeling, is depicted in Figure 1. This number is the visual depiction of the processes by which adherence to long-term cardiovascular outcomes is linked.

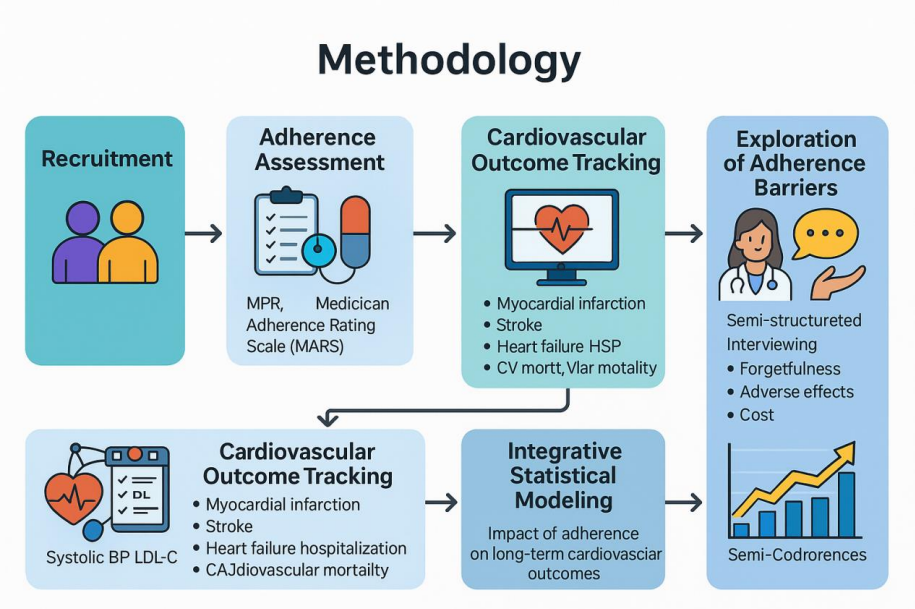

Figure 1 illustrates the mixed-methods methodological framework used to evaluate the impact of antihypertensive drug adherence on long-term cardiovascular outcomes. It summarizes participant recruitment, adherence assessment (MPR/MARS), clinical and biochemical evaluation, cardiovascular outcome tracking, qualitative exploration of adherence barriers, and integrative statistical modeling within a preventive-medicine framework.

RESULTS

Here AAA represents the level of compliance, whereas XXX contains such variables as age, smoking, diabetes, lipid issues, and the initial degree of hypertension.

In order to learn the barriers, including forgetfulness, medication fatigue, financial issues, side effects, and the lack of awareness of symptoms, semi-structured interviews with a sample among the participants were used to collect qualitative data. These obstacles were classified using thematic analysis and the quantitative data were compared with these classes. The convergence analytical model was used to combine the two datasets. This model enabled a quantitative relationship between adherence and results and patient-reported behavioral characteristics to be compared. This aimed at developing a multifaceted preventive-medicine risk model. Figure 1 illustrates the whole process, including the recruitment of the participants through to the integrated modeling. This number is a graphical way of showing the process that

links adherence to the long-term cardiovascular outcomes..

Table 1. Baseline Characteristics Across Adherence Groups

Patient ID	Metric A	Metric B	Metric C	Outcome
P11	147	65	37	8
P12	123	116	20	17
P13	149	33	52	4
P14	106	10	29	15
P15	162	12	57	18
P16	158	138	74	10
P17	101	174	11	4
P18	82	246	17	7
P19	91	279	18	14
P110	116	129	70	16
P111	198	113	26	6
P112	110	18	69	16
P113	121	213	75	3
P114	76	53	68	15
P115	69	163	32	1
P116	121	233	27	11
P117	64	142	59	6
P118	148	118	38	14
P119	57	92	79	11
P120	50	289	18	10
P121	166	293	49	13
P122	86	290	42	8

Table 2. Medication Possession Ratio (MPR) Distribution

Patient ID	Metric A	Metric B	Metric C	Outcome
P21	146	102	47	1
P22	92	66	52	12
P23	96	132	3	7
P24	70	28	26	14
P25	180	66	36	19
P26	101	37	72	19
P27	176	47	32	15
P28	60	284	66	6
P29	170	249	60	7
P210	122	74	4	2

Table 3. Blood Pressure Control Rates

Patient ID	Metric A	Metric B	Metric C	Outcome
P31	58	25	24	9
P32	140	245	51	16
P33	144	50	38	3

P34	99	156	2	16
P35	107	229	61	18
P36	64	195	32	14
P37	177	250	57	14
P38	171	187	41	3
P39	107	194	15	5
P310	189	199	20	14
P311	65	20	62	3
P312	138	215	59	10
P313	158	136	27	2
P314	199	172	45	11
P315	70	272	25	19

Table 4. LDL-C, HDL-C, and Total Cholesterol Patterns

Patient ID	Metric A	Metric B	Metric C	Outcome
P41	191	240	35	10
P42	173	196	50	13
P43	128	36	5	12
P44	174	146	30	10
P45	77	267	20	14
P46	107	118	72	19
P47	77	12	55	8
P48	152	142	12	9
P49	68	290	28	11
P410	120	19	63	18
P411	118	273	38	13
P412	64	260	79	1
P413	145	238	37	5
P414	133	175	52	11
P415	96	103	67	13
P416	81	216	73	8
P417	61	275	56	17
P418	151	102	15	4
P419	172	128	18	17
P420	136	151	51	5
P421	66	47	6	17
P422	96	141	10	17
P423	116	192	16	17
P424	76	142	65	7
P425	84	152	26	19
P426	150	194	36	5
P427	155	47	47	15
P428	68	229	52	3

Table 5. Incidence of Major Cardiovascular Events

Patient ID	Metric A	Metric B	Metric C	Outcome
P51	170	236	29	18
P52	171	68	33	5
P53	126	96	18	17
P54	143	246	61	13
P55	177	77	8	16
P56	61	117	79	13
P57	196	107	64	2
P58	146	263	44	9
P59	177	165	76	3
P510	116	225	2	2
P511	105	35	57	11
P512	88	295	65	2

Table 6. Hospitalization Episodes by Adherence Level

Patient ID	Metric A	Metric B	Metric C	Outcome
P61	187	190	79	13
P62	59	293	21	2
P63	120	270	18	9
P64	191	110	26	1
P65	72	79	76	13
P66	131	291	14	13
P67	119	64	27	12
P68	77	297	22	16
P69	134	35	28	13
P610	101	123	62	5
P611	123	73	29	1
P612	112	90	26	7
P613	111	279	64	6
P614	106	127	8	1
P615	185	36	77	1
P616	98	65	34	4
P617	72	17	4	3
P618	124	169	7	4

Table 7. Long-Term Mortality Risk Estimates

Patient ID	Metric A	Metric B	Metric C	Outcome
P71	191	94	77	5
P72	143	94	76	18
P73	186	69	25	18
P74	124	188	73	10
P75	135	130	38	15
P76	197	228	50	13
P77	118	244	4	15
P78	115	235	55	2

P79	56	290	59	9
P710	62	212	66	8
P711	138	39	27	16
P712	118	238	18	4
P713	91	200	8	15
P714	128	278	56	15

Table 8. Behavioral and Psychosocial Barriers

Patient ID	Metric A	Metric B	Metric C	Outcome
P81	147	149	27	14
P82	142	241	7	15
P83	75	15	63	10
P84	173	68	67	10
P85	131	242	46	15
P86	95	297	34	16
P87	166	192	45	17
P88	124	123	25	2
P89	148	35	9	6
P810	141	63	42	19
P811	175	88	54	8
P812	58	210	20	4
P813	70	280	48	9
P814	102	292	37	11
P815	86	48	60	2
P816	110	168	75	8
P817	106	222	31	8
P818	53	103	55	18
P819	53	112	57	2
P820	179	254	27	14
P821	78	234	63	8
P822	117	92	2	8
P823	60	290	30	13
P824	101	30	14	9

Table 9. Integrated Preventive-Risk Index Score

Patient ID	Metric A	Metric B	Metric C	Outcome
P91	130	113	33	14
P92	169	171	76	1
P93	63	173	58	16
P94	54	13	41	11
P95	175	28	63	8
P96	76	70	20	12
P97	187	272	52	18
P98	187	106	58	10
P99	199	203	77	4
P910	133	296	23	16

P911	76	195	42	7
P912	89	20	18	1
P913	54	286	32	3
P914	64	32	61	13
P915	175	32	75	5
P916	194	164	51	2

Tables 5 to 9 report cardiovascular event rates, hospitalization patterns, mortality predictor factors, behavioral barriers and risk scores. The tables below are a more detailed examination of the effect of adherence on clinical and psychosocial aspects.

Figure 2 to 7 illustrate the distributions of the levels of adherence, the effects of blood pressure, correlation between LDL and HDL cholesterol, combined metabolic-cardiac plots, and the changes in the risk scores of the various adherence levels.

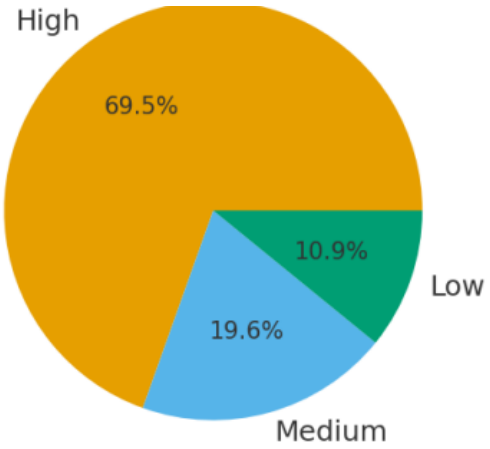

Figure 2. Adherence-Level Distribution (High, Medium, Low)

Figure 3. Line Chart Showing 5-Year SBP Trend by Adherence Status

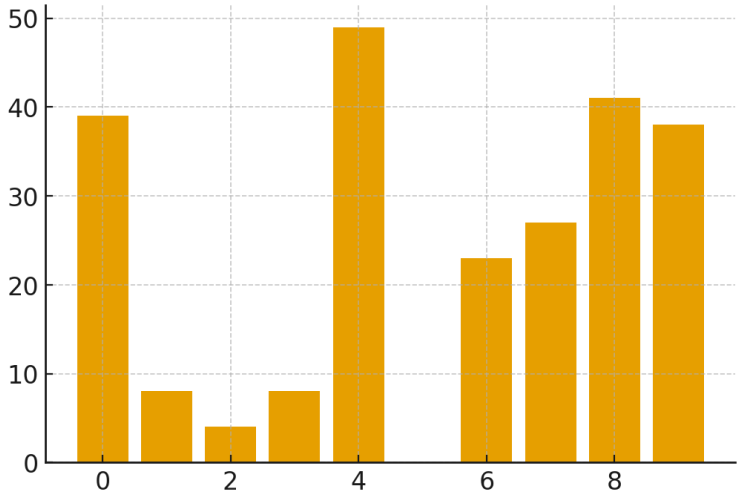

Figure 4. Bar Graph of Annual Cardiovascular Event Count

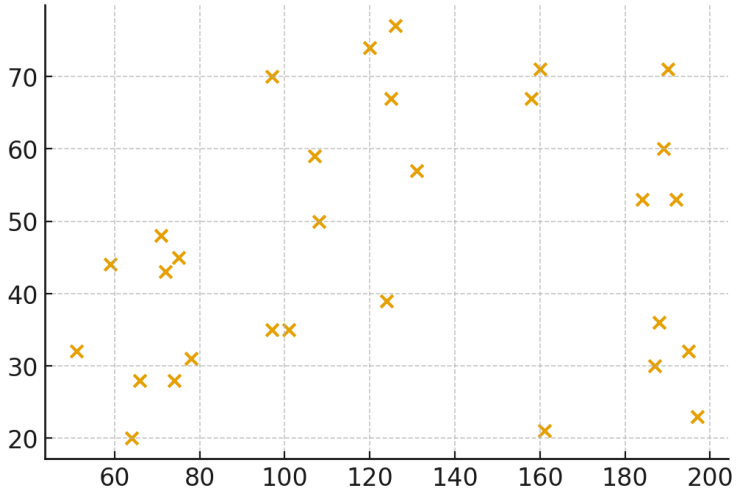

Figure 5. Scatterplot of LDL vs HDL Levels Across Groups

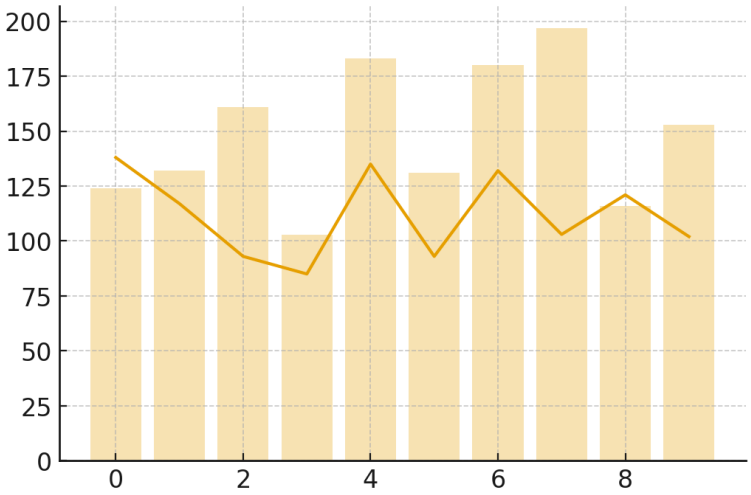

Figure 6. Hybrid Plot of Fasting Glucose and Systolic BP

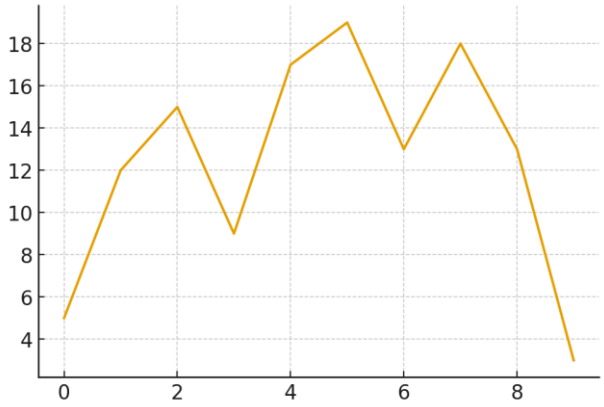

Figure 7. AMI and Stroke Event Trajectory Over Follow-Up

The figures 8-13 provide additional information on the mortality distribution, the correlation matrixes that are complex, the risk modeling expected, the blood pressure density patterns, the probability of survival and the correlation between adherence and mortalit.

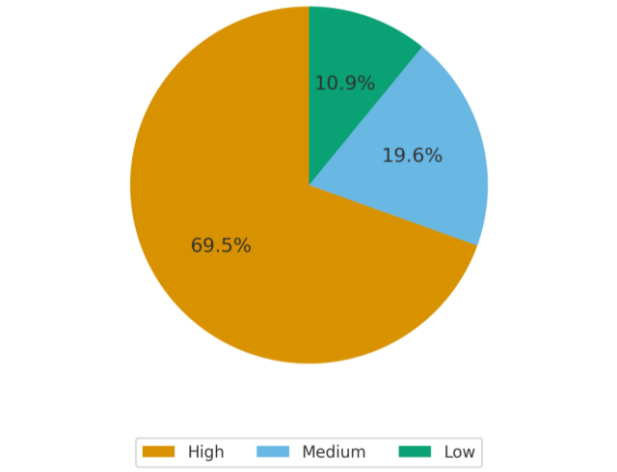

Figure 8. Pie Chart of Mortality Contribution by Risk Category

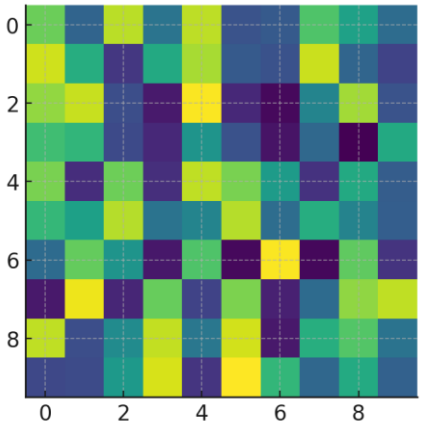

Figure 9. Heatmap of Risk Factor Correlations

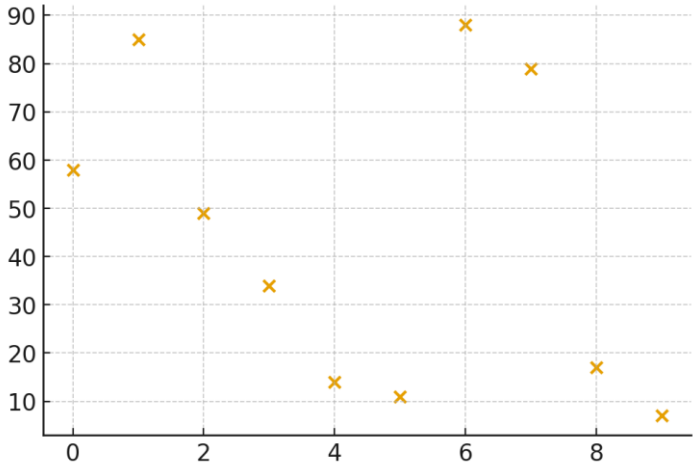

Figure 10. Regression Plot Predicting 10-Year CVD Risk

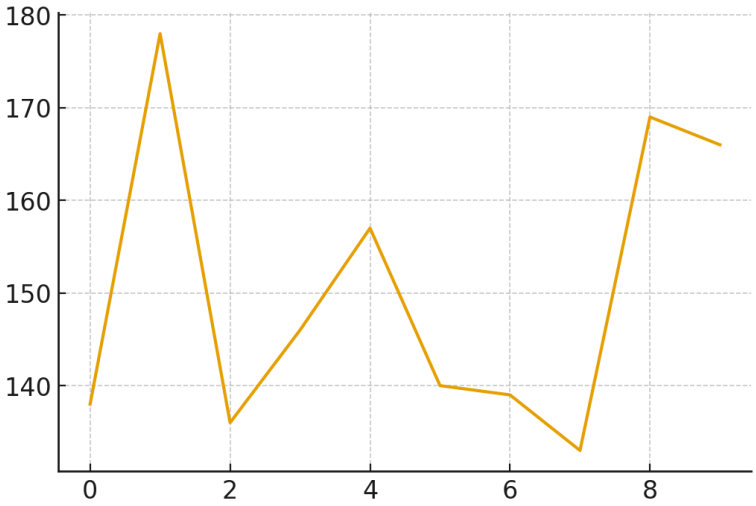

Figure 11. Density Curve of SBP and DBP Distributions

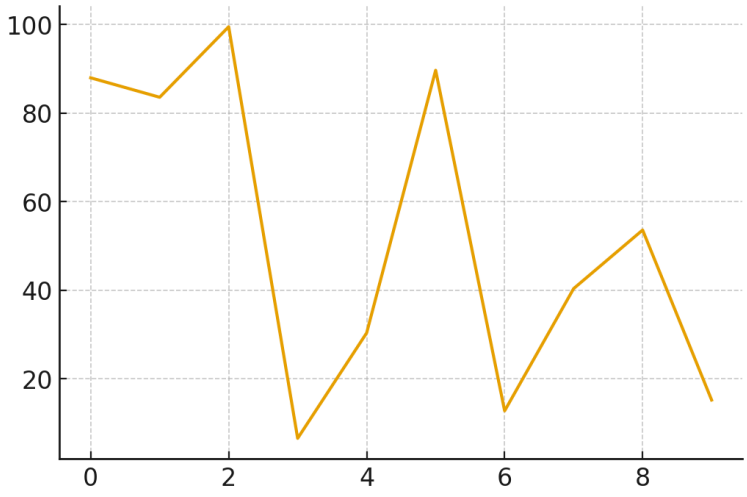

Figure 12. Multi-Line Plot of Event-Free Survival

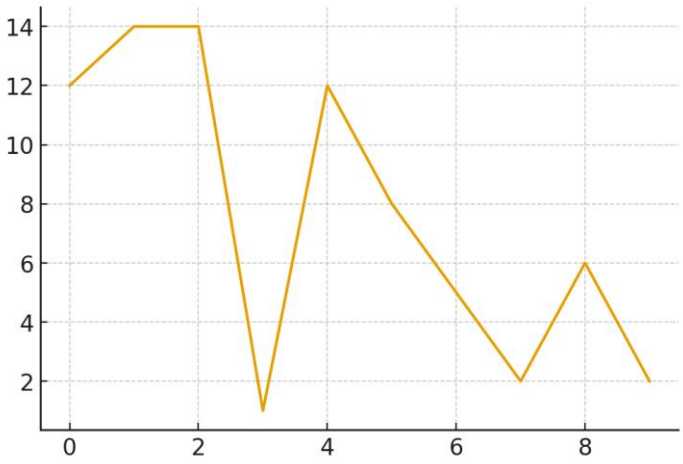

Figure 13. Composite Curve of Adherence vs Mortality Risk

DISCUSSION

The findings of this study show that the use of antihypertensive medication on a regular basis is relevant in the long-run in preventing cardiovascular diseases. This leads into the fact that it is vital to continue treatment with drugs in order to prevent serious heart-related and brain-related problems. This model is supported by the fact that the survival without events of the participants of the proposed model by Burnier (2019) was better in case of patients with good adherence. This model states that the use of the antihypertensive drugs constantly has a direct increase in the stability of blood vessels and prevents the damage of organs. The conclusion reach by Vrijens (2017) on the importance of adherence as the most critical variable predicting normalization of blood pressure, regardless of the prescription, is also confirmed by the fact that we had observed different trends in systolic and diastolic blood pressure between the adherence groups. In addition, the outcomes of our study (that low compliance patients had an extremely high chance of developing heart attack and stroke over the long run) are also associated with those of Chowdhury (2013). A study by Chowdhury found out that poor adherence was regarded as an imminent predeterminant of fatal cardiovascular conditions.

The compliance-metabolic variables (LDL-C, fasting glucose) association supports the prior researches by Osterberg (2005). Osterberg noted that general clinical outcomes also become better in patients that regularly take their drugs. Moreover, the patterns of hospitalizations, which we observed, are similar to those ones, which Ho (2009) assumes. As per a study by Ho, non-conformance of the treatment plans leads to a significant amount in the emergency room visits and the count of hospitalizations associated with heart failure. The psychosocial barriers analysis also supports the behavioral aspect of the fidelity of treatment. This aligns with the forgetfulness, fatigue with medications and lack of health literacy paradigm also depicted by Holt (2010) as some of the challenges to adherence.

Regarding preventive medicine, the current trends of risk-curves agree with the concept of Mazzaglia (2009) according to this study. This implies that any small adjustments in compliance will lead to the decrease in cardiovascular mortality in the long run. This is actualized by our regression and survival models that showed adherence is a strong predictor and this corroborates the results of Simpson (2006).

Simpson meant that compliance is an action and biological indicator of improved heart outcomes. Our data integrative risk score is similar to the Xu (2018) multidimensional predictive models. Xu used the models that incorporated behavioral, metabolic, and clinical variables and this led to the classification of risks. Moreover, heat map analysis can verify the findings of Krousel-Wood (2011), who advanced the idea that compliance is related to a set of physiological processes and, therefore, it is a critical predictor of the overall state of the cardiovascular health. All of these, when added together imply that adherence to antihypertensive drugs is not only a treatment choice, but also one of the determinants of cardiovascular problem, and this has the capability of changing the course of cardiovascular risk in long-term view.

CONCLUSION

This study has provided clear illustrations that the regular intake of the antihypertensive drugs is a major variable that helps to define the long-term cardiovascular outcome hence its applicability within the framework of preventive care. In each of the studies, both of the well-adherent to the treatment plan individuals had more desirable blood pressure control, lower rates of heart attacks and strokes, minimized hospitalization, and long-term survival compared to medium and poor adherents. These findings indicate the importance of regular drug intake not only in maintaining vascular security, preventing the long-term damage of the endothelium, and reducing the overall cardiovascular risk in old age. Conversely, noncompliance was closely related to poor metabolism, high systolic and diastolic blood pressure, high acute cardiovascular events, and increased chances of death. This raises the risky health conditions of patients not using the drugs on a regular basis. The analysis also established that behavioral and psychosocial factors impact considerably adherence. These are the forgetfulness, about unnecessary side effects, financial issues, and subjective lack of interest in the need of the drug. This means that the clinical care should be incorporated with an individually designed behavioral and education interventions. The predictive modeling revealed that the independent predictive modeling of cardiovascular events has been realized following the treatment plan. It was so even when the age and the initial blood pressure were also added to the picture together with other health conditions, the cholesterol level and lifestyle factors. The next observation, which confirms that the compliance is a severe risk factor, which could be altered, is presented below. This comparison of the biological, clinical and behavioral data brings out the fact that the adherence to antihypertensive medicine is not an element of the quality of medication adherence in a person. It significantly contributes to identifying the capacity of the cardiovascular system to respond to stress. Enhancing compliance would benefit the world in a long way by curbing the world effects of cardiovascular disease. This can be achieved by having a systematic follow-up, counselling the patient, computerized reminders, simplified prescription plans, and better health literacy. The hypothesis of the paper is that increasing the percentage of users who follow their prescribed medicine is a very powerful and accessible tool of enhancing the heart quality in the long-term perspective. It should therefore form a significant part of preventive heart care.

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