

Research Article

Lipid Profile Abnormalities as Predictors of Uncontrolled Hypertension and Cardiovascular Risk in Adults with Primary Hypertension: An Observational Cohort Study

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ABSTRACT

Background: Dyslipidemia frequently coexists with primary hypertension, potentially contributing to inadequate blood pressure control and increased cardiovascular risk.

Objective: To evaluate the association of lipid profile abnormalities with uncontrolled hypertension and cardiovascular outcomes in adults with primary hypertension.

Methods: This single-center observational cohort study included 120 adults with primary hypertension at Rashid Latif Khan University Medical College, Lahore, Pakistan, from March 2025 to March 2026. Baseline lipid profiles were evaluated in relation to subsequent blood pressure control. Multivariable logistic regression assessed independent associations, while cardiovascular events and exploratory predictive performance were also examined.

Results: Uncontrolled hypertension was observed in 68 participants (56.7%). Compared with controlled participants, those with uncontrolled hypertension exhibited higher low-density lipoprotein cholesterol (135.8 vs. 110.2 mg/dL), triglycerides (176.4 vs. 146.6 mg/dL), and lower high-density lipoprotein cholesterol (44.6 vs. 50.9 mg/dL). Adjusted analyses demonstrated significant associations with LDL-C (adjusted odds ratio [aOR] 1.54 per 10 mg/dL; 95% CI 1.23-1.94), triglycerides (aOR 1.64 per 50 mg/dL; 95% CI 1.07-2.53), and HDL-C (aOR 0.51 per 10 mg/dL; 95% CI 0.28-0.95). Eleven participants (9.2%) experienced major cardiovascular events. Incorporating lipid parameters into clinical prediction models increased the apparent area under the curve from 0.802 to 0.894.

Conclusion: Lipid profile abnormalities were independently associated with uncontrolled hypertension and improved apparent model discrimination. Larger prospective studies with external validation are required to establish their clinical predictive utility.

Keywords: Primary Hypertension, Dyslipidemia, Lipid Profile, Cardiovascular Risk, Blood Pressure Control, Ldl Cholesterol.

INTRODUCTION

Hypertension is a major modifiable risk factor for cardiovascular morbidity and mortality worldwide and contributes significantly to coronary artery disease, stroke, heart failure, and chronic kidney disease¹. Most cases of hypertension are primary (or common) hypertension and are caused by a combination of interacting genetic, metabolic, vascular and environmental influences. While there has been significant progress in the treatment of hypertension, suboptimal control of BP remains a major clinical problem, especially in people with other metabolic disorders. Maintaining elevated blood pressure levels contributes to endothelial dysfunction, vascular remodeling

and progressive target-organ damage and raises the risk of adverse cardiovascular outcomes^{2,3}.

Dyslipidemia is frequently seen in primary hypertension and is defined by high total cholesterol, low-density lipoprotein cholesterol (LDL-C), and triglycerides and low high-density lipoprotein cholesterol (HDL-C)⁴. Lipid accumulation, oxidative stress, vascular inflammation and impaired endothelial function are all abnormalities that play a role in atherosclerosis. High LDL-C can lead to the formation of plaques of atherosclerosis; high triglycerides and low HDL-C often are indicators of poor metabolism and insulin resistance. The association between hypertension and

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dyslipidemia may contribute to the acceleration of vascular injury and to significantly elevate cardiovascular risk⁵.

There are multiple pathophysiological mechanisms linking lipid abnormalities and the regulation of blood pressure. Dyslipidemia can affect the bioavailability of nitric oxide, stiffen the arteries and affect vascular smooth muscle function, which can lead to a rise in peripheral vascular resistance⁶. Dyslipidemia is known to be an atherosclerotic cardiovascular risk determinant, but the relationships of dyslipidemia with suboptimal blood pressure control are less well characterized. This relationship may also be affected by clinical factors like obesity, diabetes mellitus, renal dysfunction, and antihypertensive therapy⁷.

Lipid profiling is a simple and inexpensive tool for assessing the cardiovascular risk in hypertension⁸. In addition to conventional parameters like TC, LDL-C, HDL-C and TG, the derived indices like non-HDL cholesterol and lipid ratios can give more information about the atherogenic risk. But data on their usefulness in predicting future uncontrolled hypertension is sparse, especially when combined with other known cardiovascular risk factors. Detection of clinically significant lipid disorders can help to better stratify risk and manage the entire patient with primary hypertension⁹⁻¹¹.

This study aimed to evaluate the association of lipid profile abnormalities with uncontrolled hypertension and cardiovascular risk among adults with primary hypertension. It also aimed to determine which of the lipid parameters was independently associated with poor BP control and to evaluate contribution of these parameters to cardiovascular risk prediction.

MATERIALS AND METHODS

Study Design and Setting

The observational cohort study was carried out in Rashid Latif Khan University Medical College Lahore Pakistan from March 2025 to March 2026. A total of 120 adult participants with known primary hypertension were studied and the association of abnormal lipid profile at baseline, level of blood pressure achieved and cardiovascular outcome was examined. Demographic data, clinical parameters, biochemical measurements, antihypertensive medication use, and cardiovascular risk factors were assessed in order to identify factors related to uncontrolled hypertension that are mediated via lipid measurements. Baseline parameters were analyzed for their association with BPS at follow-up, and reported

cardiovascular events were analyzed as secondary outcomes.

Study Population and Selection Criteria

One hundred twenty (120) adults (age ≥ 18 years) with a known diagnosis of primary hypertension and baseline lipid profile data were included in the study. Eligibility was based on the clinical diagnosis documented, inclusion and exclusion criteria and availability of the information required for the assessment of the study outcome. Patients taking anti-hypertensive drugs were included regardless of the class of drug or number of drugs prescribed. People with secondary hypertension or hypertension in pregnancy or with acute medical conditions likely to affect lipid metabolism were excluded. If participants did not have one or more of the necessary clinical or biochemical measurements available, then they were not included in analyses that required the measurement. Sexes were included, so the distribution of hypertension control and associated cardiovascular risk factors could be analysed by sex.

Clinical and Blood Pressure Evaluation

Clinical assessment was performed for age, sex, body mass index (BMI), duration of hypertension, smoking status, diabetes mellitus, family history of cardiovascular disease and antihypertensive and lipid lowering drugs. BMI was measured in kg/m^2 . At baseline and at the specified follow-up assessment, the systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured. The presence of hypertension control was determined based on the resulting blood pressure measurements at follow-up. Uncontrolled hypertension was defined as SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg while controlled hypertension as SBP < 140 mmHg and DBP < 90 mmHg. The participants were then divided into two groups, controlled and uncontrolled hypertension group, for the comparison. In addition, baseline blood pressure was included in multivariable analyses to adjust for variations in baseline blood pressure.

Biochemical Assessment

The biochemical parameters measured included the serum levels of total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C) and triglycerides (TG) at baseline. Lipid values were retrieved from baseline lab reports and reported

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in milligrams per deciliter (mg/dL). Conventional clinical criteria were used to define lipid abnormalities: total cholesterol $\geq$ 200mg/dl, LDL-C $\geq$ 130mg/dl and hypertriglyceridemia $\geq$ 150mg/dl. Low HDL-C was considered <40 mg/dl in men, and <50 mg/dl in women. Non-HDL cholesterol was defined as the difference between total cholesterol and HDL-C. The total cholesterol-to-HDL-C, and triglyceride-to-HDL-C ratios were computed from the respective lipid levels. In addition to individual lipid parameters, these derived indices were also analyzed to evaluate their relationship with the control of hypertension and atherogenic lipid pattern. The combination of hypertriglyceridemia and decreased HDL-C was also considered as a combined lipid abnormality.

Outcome Assessment

The main trial result was uncontrolled hypertension at the scheduled follow-up visit based on the pre-specified blood pressure cut-off points. Secondary outcomes were change from baseline to follow-up in SBP and DBP, and the occurrence of documented cardiovascular events (CVE) and associations of individual lipid abnormalities with hypertension control. The major cardiovascular adverse events included in the analysis were nonfatal myocardial infarction, nonfatal ischemic stroke and cardiovascular death. Documented cardiovascular events were determined and differentiated between pre-existing cardiovascular disease and newly occurring events. The frequency of each event was assessed by hypertension control status and baseline lipid categories. Because of the small number of cardiovascular events, these results were assessed descriptively and not by the use of multivariable event-prediction models.

Statistical Analysis

The data were presented as mean $\pm$ standard deviation (SD) or median (IQR) for continuous variables, and as frequencies and percentages for categorical variables. Continuous variables were compared between groups using independent-samples t-test with Welch's t-test if necessary or Mann-Whitney U test for non-normally distributed measurements. The Pearson's Chi-square (or Fisher's exact test, where appropriate) was used to compare categorical variables. Demographic, clinical and lipid profile parameters were compared between the controlled and uncontrolled hypertensive patients.

Multivariable binary logistic regression was used to examine the independent associations of baseline lipid parameters with uncontrolled hypertension. Models were adjusted for antihypertensive treatment, lipid-lowering treatment, smoking status, diabetes mellitus, baseline SBP, age, and sex. To avoid the multicollinearity due to the correlation between lipid concentrations and lipid indices, individual lipid parameters were examined in separate adjusted models. Results were presented as aORs and 95% CIs. Odds ratios for continuous lipid variables were reported according to the measurement increments specified for each parameter.

Discrimination between controlled and uncontrolled hypertension was evaluated by using exploratory prediction models that included lipid parameters. A clinical model that included demographics and traditional cardiovascular risk factors was contrasted with models that included LDL-C, triglycerides, HDL-C and the combination of these variables. The area under the receiver operating characteristic curve (AUC) was used to summarize discriminatory performance and the Brier score to assess overall prediction accuracy. These measures were considered tentative measures of within-sample performance and were treated with caution as no internal or external model validation had been performed. Due to the small number of events observed, frequencies of cardiovascular events were summarized descriptively and reliable cardiovascular outcome modeling with many variables was not possible. Two-sided tests were used to determine the statistical significance ($p < 0.05$).

Ethical Considerations

Ethical review and informed-consent procedures of the study were documented as per applicable institutional requirement. Confidentiality of participants was ensured by de-identifying clinical and biochemical data to be analyzed in the context of the research. No individual patient identities were revealed in the presentation of study results, and research data were used according to the institutional confidentiality rules.

RESULTS

Baseline Demographic and Clinical Characteristics

A total of 120 adults with primary hypertension were included in the study, comprising 59 males (49.2%) and 61 females (50.8%), with a mean age of 56.2 ± 11.6 years. At follow-up, 68

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participants (56.7%) were classified as having uncontrolled hypertension, whereas 52 (43.3%) achieved blood pressure control. Uncontrolled hypertension was seen in 35 males (59.3%) and 33 females (54.1%) and there was no significant difference between males and females (p value = 0.564).

The mean body mass index (BMI) was significantly higher for the participants with uncontrolled hypertension than for the participants with controlled hypertension (29.3 ± 3.2 kg/m² versus 26.7 ± 4.1 kg/m²; $p < 0.001$). Baseline systolic blood pressure (SBP) was also higher in the uncontrolled group (152.5 ± 12.1 versus 147.2 ± 13.5 mmHg; $p = 0.028$). Participants with uncontrolled hypertension had a higher prevalence of diabetes mellitus compared to others (47.1% vs 15.4%; $p < 0.001$). In contrast, the length of

the hypertension period was prolonged in the controlled group (7.6 ± 2.9 vs 6.0 ± 3.0 years; $p = 0.004$). There were no significant differences in age, baseline diastolic blood pressure (DBP), smoking status, antihypertensive therapy, or lipid lowering therapy.

Demographic and clinical characteristics are presented in table 1. The results of continuous variables are presented as mean and standard deviation (SD) and the results of categorical variables are presented as frequency and percentage. All reported continuous-variable comparisons were made using Welch's independent-samples t-test, while all categorical comparisons were made using the Pearson's chi-square test. The comparison of sex distribution is a single overall test of the male and female participants.

Table 1. Baseline Demographic and Clinical Characteristics According To Hypertension Control Status

Variable	Total (N = 120)	Controlled (n = 52)	Uncontrolled (n = 68)	p-value
Age, years	56.2 $\pm$ 11.6	54.2 $\pm$ 11.6	57.8 $\pm$ 11.4	0.093
Male, n (%)	59 (49.2)	24 (46.2)	35 (51.5)	0.564
Female, n (%)	61 (50.8)	28 (53.8)	33 (48.5)	—
BMI, kg/m ²	28.2 $\pm$ 3.9	26.7 $\pm$ 4.1	29.3 $\pm$ 3.2	<0.001
Duration of hypertension, years	6.7 $\pm$ 3.1	7.6 $\pm$ 2.9	6.0 $\pm$ 3.0	0.004
Baseline SBP, mmHg	150.2 $\pm$ 12.9	147.2 $\pm$ 13.5	152.5 $\pm$ 12.1	0.028
Baseline DBP, mmHg	91.2 $\pm$ 7.3	90.5 $\pm$ 6.3	91.7 $\pm$ 7.9	0.357
Diabetes mellitus, n (%)	40 (33.3)	8 (15.4)	32 (47.1)	<0.001
Current smokers, n (%)	23 (19.2)	10 (19.2)	13 (19.1)	0.988
Antihypertensive treatment, n (%)	101 (84.2)	45 (86.5)	56 (82.4)	0.534
Lipid-lowering treatment, n (%)	37 (30.8)	16 (30.8)	21 (30.9)	0.989

Distribution of Lipid Profile Abnormalities

Comparison of baseline lipid profiles revealed significant differences between participants with controlled and uncontrolled hypertension. Mean total cholesterol (TC) was higher in the uncontrolled group than in the controlled group (215.3 ± 25.3 versus 190.4 ± 26.3 mg/dL; $p < 0.001$). In a similar manner, LDL-C levels were also significantly higher among cases with uncontrolled hypertension (135.8 ± 23.8 versus 110.2 ± 24.7 mg/dL; $P < .001$). In addition, the uncontrolled group had higher levels of triglyceride (TG) (176.4 ± 46.9 versus 146.6 ± 60.0 mg/dL; $p = 0.004$) while the HDL-C concentration was significantly lower (44.6 ± 9.1 versus 50.9 ± 8.9 mg/dL; $p < 0.001$). Uncontrolled hypertension group had higher LDL-C (41 [60.3%] vs 13 [25.0%]) ($p < 0.001$). Hypertriglyceridemia was present in 45 (66.2%)

and 20 (38.5%) participants, respectively ($p = 0.003$), while reduced HDL-C was observed in 36 (52.9%) and 17 (32.7%) participants ($p = 0.027$). Hypertriglyceridemia was more common in the uncontrolled group, as well as reduced HDL-C (35.3% vs 15.4%, $p = 0.015$). Other lipid indices (such as non-HDL cholesterol, TC/HDL-C ratio and TG/HDL-C ratio) were also significantly different between groups.

The lipid abnormalities were categorized with predefined values for TC (TC ≥ 200 mg/dL), LDL-C (LDL-C ≥ 130 mg/dL) and TG (TG ≥ 150 mg/dL). HDL-C levels below 40 mg/dl in men and 50 mg/dl in women were considered reduced. Non-HDL cholesterol was determined by subtracting the HDL-C from the TC and lipid ratios were derived from the respective concentrations. The mean $\pm$ SD of continuous values and frequencies and percentages of

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categorical abnormalities are presented. The results of the comparison are given in Table 2.

Table 2. Comparison of Lipid Profile Parameters between Controlled and Uncontrolled Hypertension Groups

Lipid parameter	Controlled (n = 52)	Uncontrolled (n = 68)	p-value
Total cholesterol, mg/dL	190.4 ± 26.3	215.3 ± 25.3	<0.001
LDL-C, mg/dL	110.2 ± 24.7	135.8 ± 23.8	<0.001
HDL-C, mg/dL	50.9 ± 8.9	44.6 ± 9.1	<0.001
Triglycerides, mg/dL	146.6 ± 60.0	176.4 ± 46.9	0.004
Non-HDL-C, mg/dL	139.5 ± 27.3	170.7 ± 24.8	<0.001
TC/HDL-C ratio	3.8 ± 0.8	5.0 ± 1.1	<0.001
TG/HDL-C ratio	2.9 ± 1.3	4.2 ± 1.6	<0.001
Elevated total cholesterol, n (%)	20 (38.5)	47 (69.1)	<0.001
Elevated LDL-C, n (%)	13 (25.0)	41 (60.3)	<0.001
Elevated triglycerides, n (%)	20 (38.5)	45 (66.2)	0.003
Reduced HDL-C, n (%)	17 (32.7)	36 (52.9)	0.027
High TG and low HDL-C, n (%)	8 (15.4)	24 (35.3)	0.015

Multivariable Analysis of Lipid Parameters Associated With Uncontrolled Hypertension

Multivariable binary logistic regression analyses were used to examine the associations between baseline lipid parameters and uncontrolled hypertension after adjustment for age, sex, BMI, baseline SBP, diabetes mellitus, smoking status, antihypertensive treatment, and lipid-lowering therapy. Because individual lipid measurements and derived lipid indices are correlated, each lipid parameter was evaluated in a separate adjusted model to reduce multicollinearity. Associations were expressed as adjusted odds ratios (aORs) with corresponding 95% confidence intervals (CIs). Higher LDL-C concentrations were associated with increased odds of uncontrolled hypertension, with an aOR of 1.54 per 10 mg/dL increment (95% CI, 1.23–1.94; $p < 0.001$). Triglyceride concentrations demonstrated a similar positive association (aOR 1.64 per 50 mg/dL increment; 95% CI, 1.07–2.53; $p = 0.024$). Conversely, higher HDL-C concentrations were inversely associated with

uncontrolled hypertension (aOR 0.51 per 10 mg/dL increment; 95% CI, 0.28–0.95; $p = 0.034$).

Total cholesterol and non-HDL cholesterol were also positively associated with uncontrolled hypertension, with aORs of 1.47 (95% CI, 1.18–1.81; $p < 0.001$) and 1.66 (95% CI, 1.31–2.11; $p < 0.001$), respectively, per 10 mg/dL increment. Among the derived indices, the TC/HDL-C ratio showed a positive association (aOR 6.07 per unit increase; 95% CI, 2.45–15.04; $p < 0.001$), as did the TG/HDL-C ratio (aOR 1.94 per unit increase; 95% CI, 1.29–2.93; $p = 0.002$). Although concurrent hypertriglyceridemia and reduced HDL-C demonstrated a positive estimated association, the result was not statistically significant after adjustment (aOR 2.12; 95% CI, 0.71–6.38; $p = 0.181$).

The adjusted associations are presented in Table 3. These estimates characterize associations with blood pressure control status and should not be interpreted as evidence of a causal relationship.

Table 3. Adjusted Associations between Baseline Lipid Profile Parameters and Uncontrolled Hypertension

Lipid parameter	Adjusted OR	95% CI	p-value
LDL-C, per 10 mg/dL increase	1.54	1.23–1.94	<0.001
Triglycerides, per 50 mg/dL increase	1.64	1.07–2.53	0.024
HDL-C, per 10 mg/dL increase	0.51	0.28–0.95	0.034
Total cholesterol, per 10 mg/dL increase	1.47	1.18–1.81	<0.001
Non-HDL-C, per 10 mg/dL increase	1.66	1.31–2.11	<0.001
TC/HDL-C ratio, per unit increase	6.07	2.45–15.04	<0.001
TG/HDL-C ratio, per unit increase	1.94	1.29–2.93	0.002
High triglycerides with low HDL-C	2.12	0.71–6.38	0.181

Blood Pressure Changes during Follow-up

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Blood pressure measurements demonstrated differences in changes from baseline according to hypertension control status at follow-up. Among participants classified as having controlled hypertension, mean SBP decreased from 147.2 ± 13.5 mmHg at baseline to 127.0 ± 5.1 mmHg at follow-up, corresponding to a reduction of 20.2 mmHg in the group mean. In contrast, the uncontrolled group demonstrated a smaller reduction in mean SBP, from 152.5 ± 12.1 to 151.5 ± 7.4 mmHg, representing a decrease of 1.0 mmHg.

A similar pattern was observed for DBP. Among participants with controlled hypertension, mean

DBP decreased from 90.5 ± 6.3 to 77.5 ± 5.7 mmHg, corresponding to a reduction of 13.0 mmHg. In the uncontrolled group, mean DBP decreased from 91.7 ± 7.9 to 90.7 ± 6.5 mmHg, representing a reduction of 1.0 mmHg.

Baseline and follow-up measurements are summarized in Table 4 as mean $\pm$ SD. The reported changes represent differences between the corresponding group means, calculated as follow-up minus baseline values. These descriptive differences do not constitute within-group significance tests, and no paired-change SDs or inferential estimates are presented.

Table 4. Changes in Systolic and Diastolic Blood Pressure during Follow-Up

Blood pressure variable	Controlled (n = 52)	Uncontrolled (n = 68)
Baseline SBP, mmHg	147.2 ± 13.5	152.5 ± 12.1
Follow-up SBP, mmHg	127.0 ± 5.1	151.5 ± 7.4
Mean change in SBP, mmHg	-20.2	-1.0
Baseline DBP, mmHg	90.5 ± 6.3	91.7 ± 7.9
Follow-up DBP, mmHg	77.5 ± 5.7	90.7 ± 6.5
Mean change in DBP, mmHg	-13.0	-1.0

Cardiovascular Outcomes

A major adverse cardiovascular event (MACE) occurred in 11 of 120 subjects (9.2%) during the observation period, including five nonfatal myocardial infarctions, four nonfatal ischemic strokes and two cardiovascular deaths. Of the 68 participants with uncontrolled hypertension, 10 (14.7%) experienced cardiovascular events compared with one participant (1.9%) of the 52 with controlled hypertension who experienced cardiovascular events. This difference was statistically significant in the unadjusted comparison using Fisher's exact test ($p = 0.023$).

Seven of 54 (13.0%) participants with LDL-C ≥ 130 mg/dL and four of 66 (6.1%) participants with LDL-C < 130 mg/dL experienced a cardiovascular event. For the participants with elevated triglycerides, 7/65 (10.8%) had cardiovascular events, and 4/55 (7.3%) had

events among those with triglycerides < 150 mg/dL. Events also occurred in six of 53 participants (11.3%) with reduced HDL-C and five of 67 (7.5%) with normal HDL-C concentrations.

Participants presenting with concurrent hypertriglyceridemia and reduced HDL-C had an observed cardiovascular event proportion of 15.6% (5/32), compared with 6.8% (6/88) among those without this combined abnormality. These subgroups comparisons were descriptive, and lipid categories were not mutually exclusive. Due to the small amount of cardiovascular events, the data was not sufficient to reliably model cardiovascular events in a multivariable model or to properly assess independent cardiovascular predictors. The distribution of cardiovascular events across hypertension control and lipid categories is presented in Table 5.

Table 5. Distribution of Cardiovascular Events According To Hypertension Control and Lipid Abnormalities

Clinical subgroup	Total participants	Cardiovascular events, n (%)
Overall cohort	120	11 (9.2)
Controlled hypertension	52	1 (1.9)
Uncontrolled hypertension	68	10 (14.7)
LDL-C < 130 mg/dL	66	4 (6.1)
LDL-C ≥ 130 mg/dL	54	7 (13.0)
Triglycerides < 150 mg/dL	55	4 (7.3)
Triglycerides ≥ 150 mg/dL	65	7 (10.8)
Normal HDL-C	67	5 (7.5)

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Reduced HDL-C	53	6 (11.3)
Concurrent high TG and low HDL-C	32	5 (15.6)
Without concurrent high TG and low HDL-C	88	6 (6.8)

Predictive Performance of Lipid Parameters

Exploratory prediction analyses were performed to examine whether incorporating baseline lipid parameters into a clinical risk-factor model improved discrimination between participants with controlled and uncontrolled hypertension. The area under the receiver operating characteristic curve (AUC) and the Brier score were used to assess model performance. A higher AUC value reflects a greater discriminatory ability, while a lower Brier score is a better overall prediction accuracy.

The clinical model with the demographic and traditional cardiovascular risk factors had an apparent AUC of 0.802 and Brier score of 0.179. Addition of LDL-C increased the apparent AUC to 0.852 and reduced the Brier score to 0.153. Individual models with triglycerides or HDL-C had AUC values of 0.819 and 0.815,

respectively, and Brier scores of 0.172 and 0.173, respectively.

This model that includes LDL-C, triglycerides and HDL-C in addition to the clinical predictors had the highest apparent discrimination, with an AUC of 0.894 and Brier score of 0.128. When compared with the model using clinical data alone, the combined model showed an absolute increase of 0.092 in apparent AUC and a decrease of 0.051 in Brier score.

Table 6 presents the comparative predictive performance. These findings are apparent performance in the study sample and not necessarily predictive accuracy. The observed differences should therefore be interpreted with care and confidence intervals, calibration measures and internal/external validation would be required to ascertain the reliability and generalizability of the predictive estimates.

Table 6. Apparent Predictive Performance of Clinical and Lipid-Based Models for Uncontrolled Hypertension

Prediction model	AUC	Brier score
Clinical risk-factor model	0.802	0.179
Clinical model + LDL-C	0.852	0.153
Clinical model + triglycerides	0.819	0.172
Clinical model + HDL-C	0.815	0.173
Clinical model + LDL-C + TG + HDL-C	0.894	0.128

DISCUSSION

The present study investigated the association between lipid profile abnormalities, uncontrolled hypertension, and cardiovascular risk among adults with primary hypertension⁵. The Results section findings suggest that increased total cholesterol, LDL-C, and triglyceride levels, along with decreased HDL-C levels, were related to poor control of blood pressure. Following adjustment, by the associations for relevant clinical parameters, the associations remained statistically significant for several lipid parameters. The results indicate that lipid abnormalities might be an added tool in the evaluation of patients with hypertension, but that the role of lipids alone in blood pressure control and cardiovascular risk needs to be carefully interpreted⁶.

The biological explanation for the relationship between LDL-C and uncontrolled hypertension observed in the current study is possible. Increased atherogenic lipoproteins results in endothelial dysfunction, oxidative stress, vascular inflammation and eventually vascular

stiffening⁷⁻¹². These may have negative effects on vascular function, and may lead to cardiovascular complications. A series of genetic, epidemiological and clinical evidence advanced by Ference et al. firmly cemented the importance of LDL-C in atherosclerotic cardiovascular disease. However, it is important to differentiate between LDL-C and the lack of BP control, and the known association of LDL-C and atherosclerosis, as high LDL-C does not necessarily lead to BP resistance to antihypertensive treatment¹³.

The relationships with the triglycerides and HDL-C are also in line with the metabolic abnormalities often seen in patients with hypertension. Obesity, insulin resistance and diabetes mellitus can often be associated with hypertriglyceridemia and low HDL-C, which can lead to an unfavorable cardiovascular profile¹⁴. Ginsberg et al. examined the role of triglyceride rich lipoproteins and their remnants in the residual atherosclerotic cardiovascular risk¹⁴. In the same manner, results of the Strong Heart Study revealed that combined

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hypertriglyceridaemia and low HDL-C levels were linked to a higher risk for CHD, and there was a difference between glycemic status⁶. Based on these observations, it is suggested that the evaluation should be based on the entire lipid profile and not on only the total cholesterol and LDL-C¹⁵.

Results also indicate that derived lipid indices, like non-HDL-C and the total cholesterol/HDL-C ratio might be relevant¹⁶. These interventions may help in describing the overall burden of the atherogenic lipoproteins and provide further information for cardiovascular assessment. However, these indices are based on the traditional lipid parameters, and thus their statistical linkage does not imply that they are better predictor. They will be evaluated for clinical utility based on their ability to improve existing discriminators—such as age, sex, baseline blood pressure, diabetes mellitus, smoking and treatment—with respect to discrimination, calibration, and risk classification¹⁷.

Previously prospective studies have been done on associated lipid and blood pressure abnormalities and cardiovascular outcomes. Xie et al. found an association of composite lipid risk score with incident hypertension and Wei et al. found relationships between abnormal lipid indices and hypertension and ischemic stroke risk^{4,5}. While these results do give a justification to investigate lipid-related risk in the hypertensive population, incident hypertension, uncontrolled established hypertension and cardiovascular events are different outcomes. As such, these results need to be interpreted in the context of the definitions of outcomes and follow-up in this cohort¹⁸.

The number of events observed was limited giving extra caution to the cardiovascular outcome findings. The proportions of events were higher in the uncontrolled hypertension and selected lipid abnormality groups but cannot be interpreted as independent association with cardiovascular events in a descriptive fashion¹⁹. An expanded population size and longer follow-up period with sufficient numbers of events would be needed to establish if the individual lipid parameters are independently associated with myocardial infarction, ischemic stroke or cardiovascular death. Similarly, the apparently improved discrimination in the model that added in the lipid measurement should be internally and preferably externally validated before use in clinical practice²⁰.

Study potential in clinical practice is due to the common use of lipid profile and blood pressure measurements in clinical practice. The results of these evaluations may help to identify which patients may benefit from a more detailed cardiovascular risk profile and reduction. Lipid abnormalities should never however replace direct BP measurement, adherence to medication, or investigation of other clinical factors that may contribute to the lipid abnormality. Existing clinical guidelines and cardiovascular risk calculation should continue to guide choice of antihypertensive and lipid-lowering therapies³⁻¹².

There are few limitations to be noted. The study was conducted in a single center with a limited number of participants (120) which may limit the generalizability of the results to other groups. The relatively small number of cardiovascular events hinders the development of event-based estimates and the development of multivariable cardiovascular prediction models¹²⁻¹⁵. Some other factors associated with diet, exercise, adherence to medication therapy, medication change or switching therapy, and other metabolic factors might affect associations seen. Moreover, until properly validated, the predictive ability of the lipid-based models cannot be deemed to be solid. The limitations do not detract from the study's clinical relevance, which was a clinically relevant question regarding the relationship between routine lipid measurements and blood pressure control in adults with primary hypertension¹⁶⁻²⁰.

CONCLUSION

Abnormal lipid profile can be used as a clinically relevant supplement to evaluate blood pressure control and cardiovascular risk in adult primary hypertension. High LDL cholesterol, high TC and high triglycerides with low HDL cholesterol levels were related to uncontrolled hypertension and may help in the risk stratification of cardiovascular disease. The independent prognostic value of the individual lipid parameters, however, needs to be confirmed by well-powered prospective studies using validated prediction models to predict cardiovascular events. The importance of comprehensive blood pressure and dyslipidaemia management and other modifiable cardiovascular risk factors should continue to be a key part of clinical practice.

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Conflict of Interest

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The authors declare no conflicts of interest.

Authors' Contributions

ABS, RNB, FM, SAS, MMA, and AS contributed to the study design, data interpretation, manuscript preparation, and critical revision. All authors reviewed and approved the final manuscript.

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