ORIGINAL ARTICLE

Evaluation of serum ischemia-modified albumin levels in high-normal blood pressure category

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Background: High-normal blood pressure (BP), situated inside the elevated normal range and indicative of potential hypertension, is widely acknowledged as a critical worldwide health issue. High-normal BP levels consist of a systolic measurement of 130–139 mmHg and a diastolic measurement of 85–89 mmHg. Ischemia-modified albumin (IMA) is a sign that tissues are not getting enough oxygen, which is also known as tissue hypoxia. Numerous studies indicate that IMA possesses prognostic relevance in cardiovascular diseases. Our purpose was to investigate the serum IMA levels in patients with high-normal BP. **Materials and Methods:** The study prospectively enrolled 50 participants with high-normal BP and 50 individuals with normal BP consecutively. Both groups' IMA levels were assessed and compared. All patients' echocardiograms were collected. **Results:** The IMA values were markedly elevated in the high-normal group ($P < 0.001$). The research identified a significant correlation between IMA and high-normal BP, with an odds ratio of 1.725 (95% confidence interval [CI] 1.212–2.506, $P < 0.001$). An IMA level of 348 ng/L demonstrated a 94% accuracy in predicting high-normal BP, with a 32% accuracy overall (area under the curve = 0.942; 95% CI, 0.894–0.991; $P < 0.001$). **Conclusion:** Our analysis demonstrated a strong correlation between IMA and high-normal BP.

Key words: Cardiovascular diseases, hypertension, ischemia-modified albumin

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INTRODUCTION

Hypertension (HT) is a major global health concern, predisposing individuals to cardiovascular (CV) and kidney diseases and accounting for one in eight deaths worldwide.[1] According to the 2018 ESC/ESH Arterial HT Guidelines, the high-normal blood pressure (BP) category is defined as a systolic BP (SBP) of 130–139 mmHg and a diastolic BP (DBP) of 85–89 mmHg.[2] The risk of CV mortality and morbidity significantly increases even within these ranges. For instance, a BP of 115/75 mmHg or higher correlates with increased CV death risk, with each 20/10 mmHg increment doubling this risk.[3] Importantly, studies have shown that the high-normal BP condition itself increases CV mortality and morbidity, independent of further BP elevation.[4]

Identifying reliable biomarkers to assess early CV risk in high-normal BP patients remains a challenge. Ischemia-modified albumin (IMA) has emerged as a promising candidate in this regard. Under oxidative stress, the N-terminal region of albumin loses its capacity to bind metals such as cobalt, copper, and nickel, resulting in IMA, a modified form of serum albümin.[5] Unlike many other biomarkers, which are often undetectable during early myocardial ischaemia, IMA demonstrates high sensitivity, making it valuable in detecting subclinical cardiac dysfunction.[6-8] Recent studies indicate that IMA may have greater predictive significance for structural heart diseases than for acute coronary syndromes (ACS).[5]

Given these properties, IMA could be particularly useful for high-normal BP patients, who are at increased risk

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of end-organ damage and CV complications. By screening for IMA, clinicians may gain critical insights into early CV changes, enabling timely intervention and potentially improving long-term outcomes in this high-risk group.

In contrast to established HT, high-normal BP presents an opportunity for preventive measures. Increased IMA levels in this cohort may indicate the necessity for early therapies to prevent disease development and reduce long-term CV risk. HT studies emphasize significant CV damage and systemic consequences, whereas high-normal BP entails more nuanced alterations in vascular function and oxidative stress. Examining IMA in this context may reveal distinct processes connecting oxidative stress to the increase of BP in the initial phases. Despite several studies investigating IMA in hypertensive patients, there remains a deficiency in comprehending its function in persons with high-normal BP. Investigating this link could potentially enhance the clinical use of IMA beyond its current applications in identifying severe CV diseases (CVDs) or manifest HT. Patients with high-normal BP frequently inhabit a "grey zone" where the risk is not readily discernible. Establishing a correlation between elevated IMA levels and high-normal BP should improve risk stratification models and identify patients at increased risk of CV events, even those in the borderline category. Finding a strong link between IMA and high-normal BP should make it easier to use IMA as a standard screening biomarker for early CV risk assessment, which would improve the usefulness of current diagnostic tools.

IMA has been studied as a biomarker in overt HT and severe CVD in many studies, showing that it is useful for finding myocardial ischaemia and structural heart abnormalities. Nonetheless, most of this research concentrates on patients with diagnosed HT, where vascular impairment and systemic consequences are already apparent. Individuals with a high-normal BP range – defined by a SBP of 130–139 mmHg or a DBP of 85–89 mmHg – are not well studied, even though they have a higher chance of developing overt HT and CV events. Previous research has taught us a lot about the importance of IMA in the later stages of disease, but it has not looked at its potential as an early sign of subclinical oxidative stress and ischaemia in this high-risk preclinical group. This study examines serum IMA levels in persons with high-normal BP to resolve this significant gap. Our objective is to identify early metabolic alterations that signify vascular stress during the high-normal BP phase. Assess the viability of IMA as a predictive biomarker for CV risk in the absence of manifest HT. Broaden the therapeutic use of IMA beyond its existing uses, emphasizing its significance for early risk assessment and preventive measures. Our study explores the pathophysiological alterations associated with high-normal BP and proposes a novel CV risk assessment method by comparing the limits of prior studies to ours.

METHODS

This cross-sectional study had 100 participants (50 high normal and 50 controls) who visited our clinic from August 1, 2021 to August 1, 2022. The G*Power software (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) determined the requisite minimum sample size for the investigation. It was proven that there were differences between 50 samples from the patient group and 50 samples from the control group that were statistically significant ($P < 0.05$). Differences were observed with at least 80% power. Informed consent for participation was acquired from all the participants in this investigation. The local ethics committee sanctioned the study's compliance with ethical standards and the principles outlined in the Declaration of Helsinki.

Inclusion criteria for the high-normal blood pressure group

1. Participants' ages varied from 18 to 65 years
2. SBP ranging from 130 to 139 mmHg and/or DBP ranging from 85 to 89 mmHg, as delineated by the 2018 ESC/ESH Arterial HT guidelines
3. No history of CVD (e.g., coronary artery disease [CAD] and significant valvular disease) or other comorbidities that may influence IMA levels
4. Not currently prescribed antihypertensive or lipid-lowering medicines
5. Individuals who do not smoke or have ceased smoking for a minimum of (period, e.g., 6 months).

Criteria for ınclusion in the control group

1. Participants exhibiting ideal BP readings (SBP <120 mmHg and DBP <80 mmHg)
2. No prior history of cardiovascular or systemic illnesses
3. Not taking any drugs that may affect oxidative stress or BP regulation.

Method of recruitment

1. Participants were recruited (method of recruitment, e.g., consecutively, randomly, or through a targeted outreach program at healthcare facilities)
2. Recruitment locations encompassed outpatient clinics and community health centres
3. The recruiting procedure provided equitable possibilities for participation to reduce selection bias, with the sequential enrolment of eligible participants throughout the study period.

Eligibility screening

1. BP was assessed utilising a standardized technique over (period, e.g., three visits or 1 week) to verify BP

classification
2. A comprehensive medical history and laboratory analyses were performed to rule out diseases influencing IMA levels or cardiovascular risk.

Definitions

Age, gender, smoking status, and other risk factors were recorded. The 2018 ESC/ESH Arterial HT Guidelines classified the high-normal category as a SBP range of 130–139 mmHg and a DBP range of 85–89 mmHg.[2] Individuals with normotension (<120/80 mmHg) were designated to the control group. Consumption of a minimum of one pack annually or ongoing use was classified as smoking. Patients' weights and heights were measured using calibrated instruments and standard devices. The body mass index (BMI) was calculated using kg/m².

Sphygmomanometers, both automated and manual, were used to measure BP. Prior to measuring BP, patients relaxed for a minimum of 5 min in a tranquil setting, with their backs supported and feet positioned flat on the floor. They refrained from coffee, exercise, and smoking for a minimum of 30 min before the measurement. Using a table or proper posture, we raise the person's arms to heart level during the measurement. To decrease white coat HT and other transient effects, we assessed often at 1–2 min intervals and averaged.

Exclusion of major confounders

Participants with conditions known to influence oxidative stress or IMA levels were excluded.
1. CVDs (e.g., CAD, heart failure [HF])
2. Severe valvular disease or other structural heart abnormalities
3. Chronic kidney disease or liver dysfunction
4. Acute infections, inflammatory conditions, or malignancies.

Matching demographics in study groups

1. The high-normal BP group and the control group were matched based on age and sex to minimize their confounding effects on IMA levels.

Standardized measurement protocols

1. BP was measured using a standardized method to reduce variability and misclassification
2. IMA levels were assessed using the same laboratory protocol for all participants, ensuring consistency in biomarker measurement.

Collection of relevant covariates

1. Data on potential confounders, such as smoking status, BMI, lipid profile, fasting blood glucose, and alcohol consumption, were collected for all participants.

Random recruitment and blinded analysis

1. Laboratory personnel analyzing IMA levels were blinded to the participants' BP categories to eliminate the observer bias
2. By incorporating these measures, the study aimed to isolate the independent association between IMA levels and high-normal BP while minimizing the impact of confounding factors.

Echocardiographic examinations

Two seasoned cardiologists, who were unaware of the data, supplied the echocardiographic data. The Vivid 7 GE echocardiography device (GE Healthcare, Little Chalfont, UK) was used to take a standard precordial image in left lateral decubitus.[9] All patients displayed sinus rhythm. All patients had procedural echocardiographic evaluations, including standard two dimesional, pulsed wave doppler, colour flow doppler, and M-mode techniques. The parasternal long axis left ventricular ejection fraction (LVEF), interventricular septum (IVS), posterior wall (PW), and relative wall thickness (RWT) were measured using M-mode echocardiography. To reduce respiration, we measured expiration using Doppler measurements. The sample volume was put on the tips of the mitral valves, and PW-doppler was used to measure the fastest speeds of early diastolic mitral flow (E) and late diastolic mitral flow (A).

To ensure the accuracy and consistency of echocardiographic measurements, the following procedures were implemented:

All echocardiographic examinations were performed by experienced sonographers or cardiologists who were blinded to the participants' BP categories. A subset of echocardiographic images (e.g., 15%–20% of the total sample) was randomly selected for repeated analysis by the same observer at least 2 weeks apart. The variability was calculated using the intraclass correlation coefficient (ICC) or the cardiovascular (CV) to evaluate consistency within the same observer. Another subset of echocardiographic images (e.g., the same 15%–20%) was independently analyzed by a second observer blinded to the first observer's measurements. An ICC value >0.80 was considered indicative of excellent agreement. Any significant discrepancies between observers were reviewed, and protocols were adjusted as needed to improve consistency.

Blood samples

Blood was drawn from the antecubital vein following a 12-h fast and stored at −80°C. The tests encompassed biochemical markers (glucose, creatinine, lipid profile, and IMA) as well as full blood count metrics (haemoglobin concentration and leukocyte count). Serum IMA concentrations were measured using an ELISA kit (Cloud-Clone Corp., USA;

CEA825Hu). The coefficients of intraassay and interassay variability were <10% and <12%, respectively.

Statistical analysis

Statistical data were acquired using the SPSS software for Windows version 22 (SPSS Inc., Chicago, IL, USA). The distribution type was ascertained by the Kolmogorov–Smirnov test. Normal distributions were expressed as mean ± standard deviation, while nonnormal distributions were expressed as median. Categorical data were represented as a percentage of the Chi-square test outcome. The percentage of absent data for each variable was evaluated and documented. If the percentage of absent data was modest, the effect on the entire analysis was deemed inconsequential. Univariate and multivariate regression models were employed to identify the final causes of high-normal BP. Receiver operating characteristic analysis was employed to ascertain the cut-off value of IMA for predicting high-normal BP. Pandlt; 0.05 indicated statistical significance.

RESULTS

Table 1 displays the demographic, laboratory, and echocardiographic findings of this investigation. The BMI was markedly elevated in the high-normal group ($P = 0.002$). Furthermore, SBP, DBP, and IMA values were markedly elevated in the high-normal group compared to the control group ($P < 0.001$). Among the echocardiographic measures, IVS and PW were significantly elevated in the high-normal group ($P = 0.012$, $P = 0.008$, respectively), although LVEF, RWT, left ventricular myocardial ındex (LVMI), and E/A ratio exhibited no significant differences between the groups.

In the linear regression analysis, IMA levels were independently correlated with high-normal BP ($P = 0.038$). This suggests that elevated IMA levels are statistically significantly associated with high-normal BP, even after controlling for any confounding variables. The logistic regression model was used to test the prediction power of IMA for high-normal BP, using data with a $P < 0.025$ from linear regression analysis. This analysis indicated that IMA levels were a significant predictor of high-normal BP (odds ratio = 1.725, 95% confidence interval [CI] 1.212–2.506, $P < 0.001$). This indicates that for every unit rise in IMA levels, the likelihood of experiencing high-normal BP is 1.725 times higher, with a 95% CI confirming the statistical significance of this finding, ruling out random chance [Table 2]. An IMA level of 348 ng/L predicted high-normal BP with a sensitivity of 94% and a specificity of 32% (area under the curve = 0.942; 95% CI, 0.894–0.991; $P < 0.001$) [Figure 1].

Table 1: Characteristics of the study population

	Controls (*n*=50)	High-normal group (*n*=50)	*P*
Age (years)	60.2±3.6	63.3±4.8	0.202
Gender, *n* (%)			
Male	23 (46)	24 (48)	0.864
Smoking, *n* (%)	16 (32)	20 (40)	0.212
BMI (kg/m^2)	26.1±0.8	27.1±1.0	0.002
SBP (mmHg)	105.4±4.2	130.6±3.8	<0.001
DBP (mmHg)	72.2±3.1	86.8±4.5	<0.001
Glucose (mg/dL)	91.6±4.7	98.4±5.4	0.456
Creatinine (mg/dL)	0.7±0.1	0.9±0.1	0.375
eGFR (mL/min)	92.2 (57.4–105.6)	98.2 (61.4–105.6)	0.574
IMA (ng/mL)	248.1±87.9	375.1±89.2	<0.001
TC (mg/dL)	188.4±35.3	190.6±34.1	0.487
TG mg/dL	178.1±26.5	182.4±34.8	0.342
HDL (mg/dL)	38.5±8.4	36.1±9.7	0.426
LDL (mg/dL)	103.4±21.7	111.3±23.4	0.636
WBC (10^3×μL)	9.1±1.9	9.8±1.7	0.382
Hgb (g/dL)	12.7±0.6	12.5±1.2	0.785
Echocardiography			
LVEF, (%)	55.4±4.9	55.1±3.7	0.840
IVS (mm)	10.4 (8.4–14.2)	11.9 (8.1–15.5)	0.012
PW (mm)	9.2 (6.3–12.4)	10.4 (5.8–13.1)	0.008
RWT (mm)	0.4±0.1	0.6±0.2	0.567
LVMI (g/m^2)	90.6±9.4	92.4±9.5	0.354
E/A	0.9±0.2	0.6±0.1	0.112

BMI=Body mass index; DBP=Diastolic blood pressure; E/A=Early diastole/late diastole ratio; HDL=High density lipoprotein; Hgb=Hemoglobin; IVS=İnterventricular septum; LDL=Low density lipoprotein; LVEF: Left ventricular ejection fraction; LVMI=Left ventricular mass index; PW=Posterior wall; RWT=Relative wall thickness; IMA=İschemia modified albumin; TC=Total cholestrol; TG=Triglyceride; WBC=White blood cell count; SBP=Systolic blood pressure; eGFR=Estimated glomerular filtration rate

DISCUSSION

Our research suggests that people with high-normal BP have significantly higher levels of IMA. This group was previously undervalued for its possible CV risks. IMA could also predict high-normal BP on its own, which suggests it could be used as an early CV risk biomarker.

Connecting results to the literature

Numerous studies have linked high-normal BP, although not classified as HT, to elevated cardiovascular morbidity and mortality.[10,11] Nonetheless, the molecular markers indicating subclinical harm in this population have remained little known until recently. Our study shows how important oxidative stress is in the early stages of heart disease caused by high BP by finding higher levels of IMA in people with high-normal BP.

IMA is a changed form of albumin that happens because of oxidative stress and ischaemia. It has been linked to serious heart problems like ACS, HF, and end-organ damage from high BP.[12-14] Our findings augment

Table 2: Independent determinants of high-normal blood pressure

	Univariate analysis			Multivariate analysis		
	Coefficients	95% CI	*P*	OR	95% CI	*P*
Smoking	0.031	−0.153–0.216	0.738			
Age	−0.054	−0.102–0.018	0.356			
LDL	−0.032	−0.104–0.154	0.296			
LVEF	0.004	−0.009–0.015	0.853			
IMA	0.825	0.111–1.654	<0.001	1.725	1.212–2.506	<0.001
LVMI	0.052	0.012–0.614	0.338			

Variables with *P*<0.25 in univariate regression were included into multivariate regression. LVEF=Left ventricular ejection fraction; LVMI=Left ventricular mass index; IMA=İschemia modified albumin; LDL=Low density lipoprotein; OR=Odds ratio; CI=Confidence interval

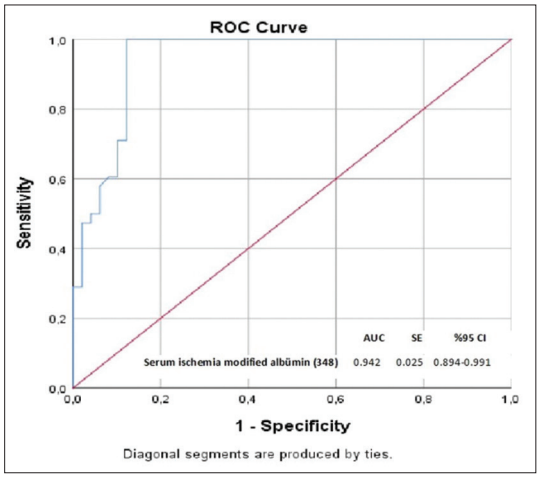

Figure 1: Receiver operating characteristic analysis to determine the cut-off value of ıschemia-modified albumin in predicting high-normal blood pressure. ROC = Receiver operating characteristic; CI = Confidence interval; AUC = Area under curve; SE = Standart error

previous data by demonstrating that IMA levels are also raised in persons with high-normal BP, a cohort typically regarded as having a lesser CV risk than hypertensive patients.

As with other studies on preHT,[15,16] the lower E/A ratio found in people with high-normal BP in our study suggests early diastolic dysfunction. This suggests that structural and functional alterations in the heart may commence even at the high-normal BP level. The fact that there weren't any big differences in LVMI values between the groups in our study could mean that heart remodelling is still in its early stages in people with high BP. The identified correlation between high-normal BP and an increased BMI–a recognised component of HT risk–highlights the necessity of addressing metabolic variables in this demographic.

This work makes a significant contribution to the literature by examining IMA levels in patients with high-normal BP for the first time. The IMA test may be able to predict CV risk early in adults who don't have high BP but may have other risk factors for future CV events. This is different from earlier studies that only looked at HT or high-risk groups.[12,17,18]

The clinical ramifications are significant. Higher levels of IMA may serve as an early warning sign, allowing quick action to be taken in people with high-normal BP who are at risk of developing HT or other heart problems. With more and more attention being paid to preventive cardiology, adding IMA testing to the ways that people with high-normal BP are evaluated for risk may give us more information about their cardiovascular risk profile.

The research indicated that an IMA level of 348 ng/L was indicative of high-normal BP, exhibiting a sensitivity of 94% and a specificity of 32%. The elevated sensitivity suggests that this cutoff effectively identifies a substantial number of individuals with high-normal BP; nevertheless, the poor specificity presents considerable issues about its practical implementation. A specificity of 32% indicates that a significant proportion of persons having high-normal BP would also yield positive results for raised IMA levels. The elevated incidence of false positives may result in unwarranted concern, additional testing, or interventions for persons who do not genuinely have high-normal BP. The enhanced sensitivity indicates that IMA testing may serve as an effective preliminary screening instrument for detecting persons predisposed to HT. Nevertheless, the low specificity suggests that it is unwise to depend exclusively on this biomarker for a conclusive diagnosis. To augment the practical applicability of IMA levels, it may be advantageous to employ this test alongside additional diagnostic criteria or risk assessment instruments. This methodology may assist clinicians in making more informed decisions and diminish the probability of misdiagnosis.

Other factors, such as ageing, oxidative stress, and metabolic disorders like obesity, also affect IMA levels.[18,19] This requires a meticulous evaluation of potential confounders when analysing IMA levels in clinical contexts.

The connection between high BP and IMA is new, and it shows that there is still a lot of research to be done on early signs of CV risk. Most of the previous research on biomarkers for HT has been focused on advanced stages of the disease or serious cardiac problems, ignoring people with high BP. Although not classified as HT, this

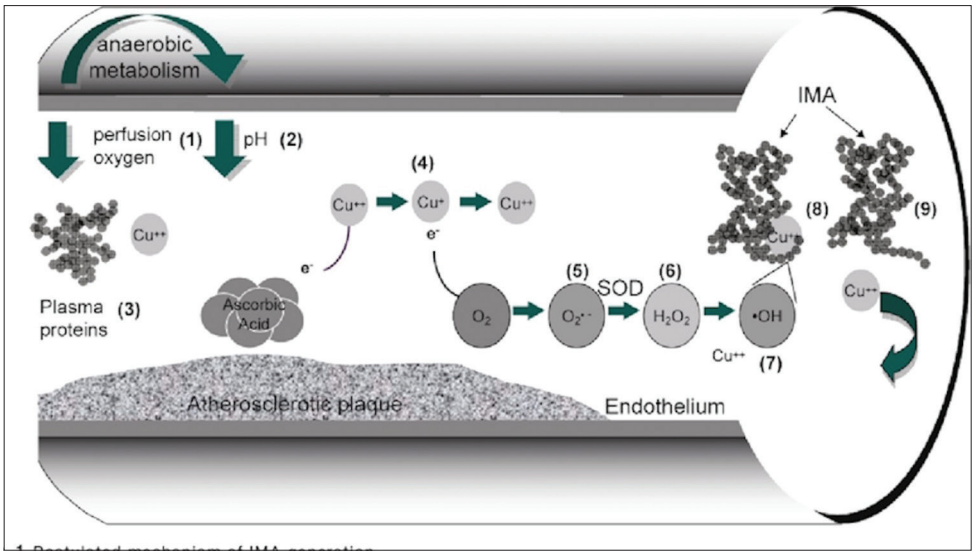

Figure 2: Graphical abstract. IMA = Ischemia-modified albumin; SOD = Superoxide dismutase

category acts as a precursor to overt HT and is associated with long-term CV risks. Biomarkers distinguish IMA by indicating oxidative stress, a fundamental mechanism that contributes to endothelial dysfunction and the initial CV injury [Figure 2]. In contrast to conventional biomarkers, like C-reactive protein or lipid profiles, which reflect generalized inflammation or lipid irregularities, IMA specifically indicates ischaemic alterations at the molecular level. Because it is so sensitive to oxidative stress, it is very good at finding small changes in people whose BP is normal before they cause major organ damage.

High-normal BP, an early CV risk indicator, independently correlates with increased IMA levels. This discovery is noteworthy, as it indicates a possible instrument for earlier intervention, focussing on individuals who may otherwise remain unrecognised in standard clinical evaluations. Moreover, the determination of an IMA threshold enhances its therapeutic utility by facilitating risk categorisation in patients with high normal BP. In the future, researchers should compare how well IMA works with other new biomarkers at predicting CV events in this group of people. Adding IMA to a group of risk assessment tools might help doctors make more accurate early diagnoses and better tailor their interventions.

Our results show a strong link between higher IMA levels and high-normal BP. This suggests that IMA could be used as an early indicator of CV risk in this group of people. This differs from previous studies that mainly concentrated on IMA in overt HT or CVDs. Research by Toker *et al*.[17] and Roy *et al*.[13] demonstrated heightened IMA levels in hypertensive and older cohorts, linking this elevation to persistent oxidative stress and endothelial injury. Nevertheless, these investigations failed to recognise high-normal BP as a separate group and did not investigate the significance of IMA in forecasting early CV alterations in prehypertensive conditions.

Possible explanations for discrepancies

Study population

Previous studies often focused on individuals with diagnosed HT or CVDs, characterised by significantly elevated oxidative stress and IMA levels. Our emphasis on high-BP patients may have shown more complicated alterations produced by early oxidative stress rather than late disease processes.

Methodological variations

Disparities in IMA measurement methodologies, research methods, and demographic characteristics of populations may account for the inconsistencies. Our study excluded participants with comorbidities, including diabetes and CAD, thereby minimising confounding variables but restricting direct comparisons with more extensive investigations. In clinical settings, IMA has been studied a lot in sudden events like myocardial infarction or HF, where high levels of IMA show that there has been acute ischaemic injury. IMA can be used to prevent problems rather than diagnose them, as shown by our study of persistent, subclinical oxidative stress in people with high-normal BP.

Longitudinal studies

To elucidate the therapeutic implications of heightened IMA levels in individuals with high normal BP, a longitudinal study is important. Such studies could ascertain whether elevated IMA levels forecast the advancement of HT, CVDs, or other organ damage.

Combination biomarker panels

The use of other biomarkers or clinical factors may enhance the effectiveness of IMA, given its low specificity. Exploring multimarker methodologies may enhance diagnostic precision and risk assessment.

Effects of ınterventions

Research should investigate if lifestyle improvements, such as exercise or dietary changes, lower IMA levels in patients with high-normal BP. Understanding that higher IMA can be reversed may help you decide if it can be used as a risk indicator that can be changed.

Clinical significance of ıschemia-modified albumin in high-normal blood pressure

The clinical importance of IMA in people with high-normal BP comes from its ability to show early signs of cardiac disease risk. High-normal BP, which is often a sign of pre-HT, is linked to changes in the heart that aren't obvious, like endothelial dysfunction, left ventricular remodelling, and higher oxidative stress. These alterations are indicators of HT and CV incidents. Identifying biomarkers that can detect these abnormalities early is essential for preventive efforts.

IMA serves as a biomarker because of its susceptibility to oxidative stress, a fundamental factor in the pathogenesis of high-normal BP. Increased IMA levels signify ischaemic alterations and oxidative injury, potentially arising prior to the onset of overt HT. IMA is especially significant in recognising individuals who may otherwise be asymptomatic yet are at increased risk for long-term CV problems.

Preventive and therapeutic strategies

As new information comes in linking high-normal BP to subclinical CVD, a proactive treatment strategy makes sense. Lifestyle therapies, including consistent physical exercise, dietary changes, and stress management, are fundamental to the treatment of high-normal BP.[20,21] Recent research indicates that nontraditional therapies, such as stretching programs, may be equally efficient as aerobic exercise in lowering BP and oxidative stress.[20]

High-risk patients may require early pharmacological treatment. High BP patients with CV risk factors such as age, obesity, or glucose intolerance should get antihypertensive monotherapy.[20] Integrating IMA levels in this decision-making process could enhance treatment plans and optimise outcomes.

Study limitations and future directions

While our study provides novel insights, it has limitations that warrant acknowledgment. First, the cross-sectional design limits our ability to establish causality between high-normal BP and elevated IMA levels. Longitudinal studies are needed to determine whether IMA levels predict progression to HT or future CV events.

Second, our study focused on a relatively small population. Larger, multi-center studies are needed to validate our findings and explore the generalizability of IMA as a biomarker across diverse populations.

Finally, the potential influence of unmeasured confounders, such as dietary habits, stress levels, or undiagnosed comorbidities, cannot be ruled out. Future researchs are warranted to explore alternative cutoff values or combinations of biomarkers that could improve specificity without sacrificing sensitivity. This would aid in refining the predictive value of IMA levels in the context of high-normal BP.

CONCLUSION

This is the first study to show a link between high BP and high levels of IMA. This suggests that IMA could be used as an early biomarker for assessing cardiovascular risk. The findings highlight the significance of early identification and intervention in patients with high-normal BP to reduce long-term cardiovascular risks. These results need to be confirmed by more research, and IMA testing should be looked into as a possible way to prevent and treat high-normal BP.

Author contributions

O.T., A.S. contributed to the conception and design of the work; O.T., A.S. contributed to the acquisition, analysis, and interpretation of data; O.T., A.S. drafted the manuscript; O.T., A.S. critically revised the manuscript. All authors gave final approval and agreed to be accountable for all aspects of work ensuring integrity and accuracy.

Ethics committee approval

All methods were carried out in accordance with the Declaration of Helsinki. The Ethics Review Committee of Adiyaman University approved the study and written informed consents were obtained (2021/05-25). The informed consent to participate was obtained from all of the participants in this study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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