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ORIGINAL ARTICLE

Central Retinal Artery Doppler Indices Change in Hypertensive Adults: A Case-Control Study

Shaymaa Khalid Abdulqader,[1] Lubna Hasan Najm,[2] Noor Yousif Abed,[3] Nabeeha Najatee Akram[4]

Abstract

Background/Aim: Hypertension had significant microvascular complication involving the ocular circulation. Colour Doppler imaging (CDI) using various flow indices can be used to assess the blood flow properties of the central retinal artery (CRA) in hypertensive adults. Aim of study was to evaluate the differences in CRA Doppler indices between normotensive and hypertensive individuals.

Methods: This case-control study design was undertaken in the Ultrasound unit at Al-Kindy teaching hospital for 3 months (January 2025 to March 2025), including 60 healthy controls and 60 young hypertensive patients on treatment. For each patient, two sets of data were gathered: demographic data including (age, gender and the body mass index BMI) and measurements of the Doppler indices of the CRA including the pulsatility index (PI), resistive index (RI), flow velocities: peak systolic velocity (PSV), end diastolic velocity (EDV) and arterial diameter (D). Doppler indices were compared and analysed between the cases and controls.

Results: Hypertensive patients show a not significantly decreased PSV and EDV in comparison with the control group ($p = 0.122$ and 0.05, respectively). However significant increases in RI and PI were detected in hypertensive group ($p < 0.001$ and 0.003, respectively). The hypertensive patients showed a significantly decreased luminal diameter of the CRA in comparison to the control group ($p < 0.001$). For RI, the AUC was 0.837, 95 % confidence interval (CI) = 0.755 - 0.918, $p < 0.001$. The sensitivity and specificity of RI at cutoff = 0.635 were 88.3 % and 70 %, respectively.

Conclusion: There was a significant difference in Doppler indices of the CRA in hypertensive patients compared with the non-hypertensive patients. Among them, RI exhibited the highest diagnostic accuracy.

Key words: Retinal artery; Ultrasonography, Doppler, colour; Hypertension.

1. Department of Radiology, Al-Kindy College of Medicine, University of Baghdad, Baghdad, Iraq.
2. Department of Radiology, Medical City, Renal Disease and Transplant Centre, Baghdad, Iraq.
3. Department of Radiology, College of Medicine, Al Fallujah University, Fallujah, Iraq.
4. Department of Paediatrics, College of Medicine, Mustansiriyah University, Baghdad, Iraq.

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Corresponding author:
SHAYMAA KHALID ABDULQADER
E: shaymaa.k@kmc.uobaghdad.edu.iq

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Introduction

Elevated blood pressure remains a global health challenge, exerting significant short and long-term negative cardiovascular consequences.[1] The microvascular complication, notably complications involving the ocular circulation being a pronounced consequence of high blood pressure in adults.[2] Chronically elevated blood pressure is associated with retinal microvascular alterations, including arterial narrowing increased vascular resistance, haemorrhage and microaneurysms, arteriovenous nicking, cotton wool spots and oedematous optic disc.[3]

The central retinal artery (CRA), as a main blood

supply to inner retina, play a critical role in detecting hypertension-induced retinal complications.[4, 5] Recent advances in imaging technique enabled early detection of CRA-related changes in hypertension patients. Some of these techniques hindered by invasive nature including fundus fluorescein angiography, while the cost and limited availability represent major obstacles for other imaging modalities including retinal vessel analyser. The optical coherence tomography angiography represents a revolution in imaging modalities as it enables the detection the CRA -related changes in hypertensive adults.[6] However, its high cost and limited availability especially in low recourse countries limited is applicability in this field.

In a low resource country, Doppler ultrasonography of CRA has emerged as valuable non-invasive imaging modality for evaluating the retinal hemodynamics.[7, 8] By quantifying blood flow indices, including peak systolic velocity (PSV), end-diastolic velocity (EDV) and deriving parameters such as the resistive index (RI) and pulsatility index (PI), it provides crucial insights into vascular resistance and perfusion within the retinal circulation.[9, 10] This technique offers anatomical advantages due to the sonolucent nature of the ocular media and the relatively superficial location of the CRA, allowing for high-resolution imaging with minimal interference from surrounding structures. Moreover, CRA Doppler metrics have demonstrated clinical utility in detecting and monitoring microvascular alterations in systemic conditions such as hypertension, diabetes mellitus and atherosclerosis, often preceding overt fundoscopic changes.[11, 12] As such, CRA Doppler ultrasonography represents an important adjunct in the early identification and risk stratification of patients with systemic microvascular disease.

Previous studies demonstrated that hypertensive adult exhibited a significantly reduced blood flow velocity in CRA. The high prevalence of hypertension in Iraqi adult and minimal prior research in Middle East cohorts led to absence of local reference value in CRA velocimetry. The purpose of this study was to assess Doppler velocimetry alterations in the CRAs among hypertensive Iraqi adults and to identify a predictive parameter for hypertensive microvascular changes.

Methods

This case-control study was undertaken in the Ultrasound Unit at Al-Kindy Teaching Hospital for 3 months (January 2025 to March 2025) with 120 participants voluntarily enrolled in the study. The study was authorised by Al-Kindy College of Medicine's Ethical Committee. Verbal consent was obtained from each participant before including them in the study.

All hypertensive patients met the 2017 ACC/AHA criteria (BP ≥ 130/80 mm Hg or receiving antihypertensive treatment). Blood pressure classification followed standard guidelines, with hypertensive individuals having BP ≥ 130/80 mm Hg or being on antihypertensive medication, while normotensive individuals had BP < 130/80 mm Hg without any treatment.[13] Accordingly, the participants were divided into two groups: (cases) included 60 adult patients with a history of hypertension on treatment and (control) included 60 normotensive adults.

Age < 18, history of systemic disease (including stroke, diabetes mellitus, dyslipidaemia, connective tissue disease and vasculitis), medical or surgical eye disease and previous ocular surgery were all exclusion criteria from the study. All participants underwent a fundal screening examination using direct and indirect ophthalmoscopy conducted by an experienced ophthalmologist to exclude ophthalmic diseases and evaluate the intraocular pressure.

Ocular ultrasound examination

A CRA Doppler ultrasound exam was performed by same experienced radiologists. The GE LOGIC S8 ultrasound device was used to perform a handheld ocular ultrasound exam using high resolution linear array probe (8-18 MHz) (Figure 1). All participants were examined in the supine position with high resolution linear transducer. After applying conduction gel, the linear probe was gently positioned over the patient's closed upper eyelid without pressure in order not to affect the intra-ocular pressure. Keeping the participants' eyes forward and their eyelids closed without squeezing them, scanning both eyes in transverse and sagittal planes was performed.

Gray-scale (B mode) sonography was mostly performed at first to examine the orbit's anatomy and exclude ocular diseases such as drusen, tu-

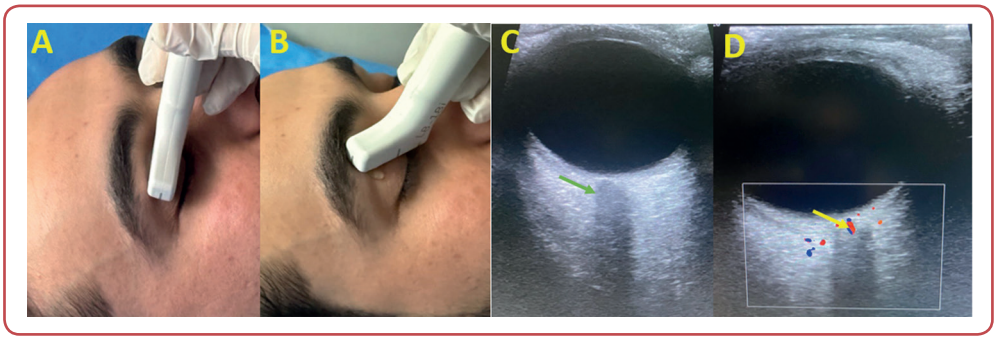

Figure 1: A) transverse position of the probe during ocular examination. B) longitudinal position of the probe. C) Ultrasound image of the eyeball (B-mode) for localisation of the optic nerve (green arrow). D) A flow Doppler sonographic image of the eyeball shows the central retinal artery (yellow arrow).

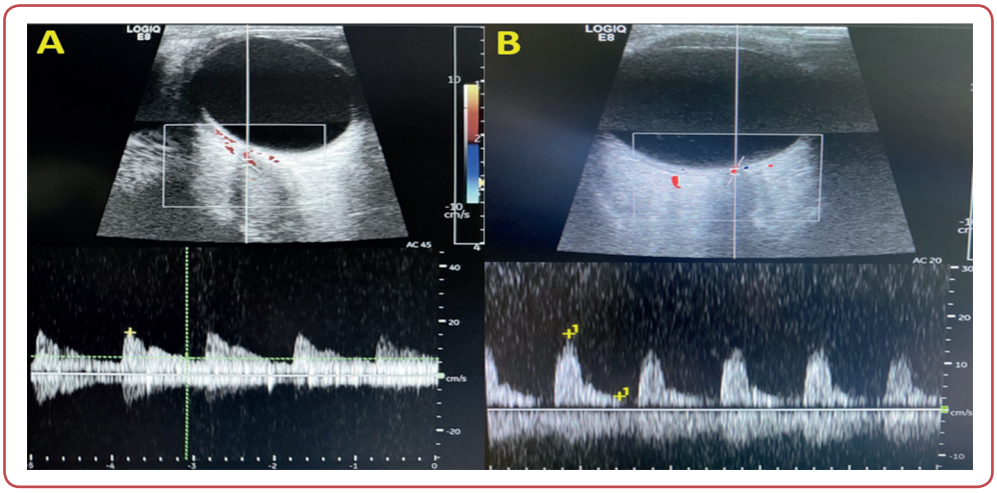

Figure 2: Pulsed wave ultrasound. A) Control group shows low resistance flow through the central retinal artery, RI = 0.6. B) hypertensive group, show high resistance flow through the central retinal artery, RI = 0.8.

mours, or inflammatory conditions. After visualisation of the optic nerve as a hypoechoic band, the CRA was detected by a colour flow Doppler and then a pulsed wave cursor was applied and flow data was then acquired (Figure 2).

The ultrasound beam angle was maintained less than 50. During the examination, the patient was instructed to keep their eyes closed and to stay relatively still. The peak systolic and end diastolic velocities of the CRA were expressed in cm/s while the RI, PI indices were measured by the ultrasound device software. Both eyes were examined separately in each case and the average measurements from both sides were considered.

Statistics

SPSS version 25 was used for all statistical analyses (IBM Corp, Armonk, NY). A statistically significant two-tailed p-value was defined as less than 0.05. Continuous variables (age, BMI, Doppler parameters) were reported as mean ± standard deviation (SD), Categorical variables (sex) were summarised as frequencies and percentages. Independent samples t-tests compared means between hypertensive and normotensive groups (BMI, PSV, EDV, RI, PI, diameter). Using the receiver operating characteristic (ROC) curve, the predictive value of Doppler indices in CRA microvascular alterations prediction was assessed.

Results

A total of 120 individuals were enrolled in the study, with 60 classified as hypertensive and 60 as normotensive. Age and sex distribution of participants were not statistically significant concerning their blood pressure state ($p = 0.788$, $p = 0.52$), respectively. The hypertensive participant demonstrated a noticeably higher body mass index (BMI) mean than normotensive participants ($p < 0.001$) (Table 1).

Table 1: Clinical and demographic features of hypertensive and normotensive participants

Variables	Hypertensive (n = 60)	Normotensive (n = 60)	p-value
Age, mean ± SD (years)	61.2 ± 9.5	60.4 ± 12.1	0.788
Sex, n (%)			
Male	38 (63.3)	20 (33.3)	0.52
Female	22 (36.7)	40 (66.7)	
BMI, mean ± SD (years)	32.6 ± 7.2	28.9 ± 3.8	< 0.001*

BMI: body mass index, SD: standard deviation;

Table 2: Comparison of Doppler indices of central retinal artery (CRA) in hypertensive and normotensive participants

Parameters	Hypertensive	Normotensive	p-value
Peak systolic velocity (PSV)	10.56 ± 1.74	11.97 ± 3.12	0.122
End diastolic velocity (EDV)	3.07 ± 1.18	4.32 ± 1.38	0.05
Resistive index (RI)	0.74 ± 0.12	0.61 ± 0.08	< 0.001*
Pulsatility index (PI)	1.11 ± 0.29	0.93 ± 0.18	0.003*
Arterial diameter (D)	0.06 ± 0.01	0.08 ± 0.01	< 0.001*

On CRA Doppler ultrasound exam, three parameters were significantly higher in hypertensive adult in comparison to normotensive adults these include RI, PI and D with statistical significance ($p < 0.001$, $p = 0.003$, $p < 0.001$, respectively). Both PSV and EDV show statistically not significant differences between both groups ($p = 0.122$, $p = 0.05$), respectively (Table 2).

The predictive value of CRA velocimetry in hypertensive microvascular changes were evaluated using the ROC curve. For RI, the AUC was 0.837, 95 % CI = 0.755 - 0.918, $p < 0.001$. The sensitivity and specificity of RI at cutoff = 0.635 were 88.3 %, 70 %, respectively. For PI, the AUC was 0.693, 95 % CI = 0.585-0.80, $p = 0.003$. The sensitivity and specificity of PI at cutoff = 1.125 were 55 %, 90 %, respectively. While for D, the AUC was 0.742, 95 % CI = 0.636 - 0.848, $p < 0.001$. The sensitivity and specificity of RI at cutoff = 0.065 were 90 %, 56.7 % respectively (Figure 3).

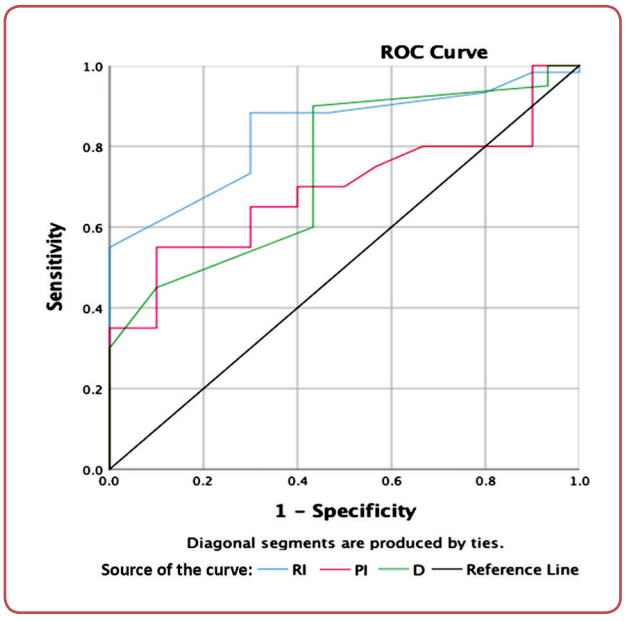

Figure 3: ROC curve for Doppler ultrasound parameters in predicting hypertensive microvascular changes

Discussion

In the current study three Doppler ultrasound parameters of the CRA demonstrate promising predictive value for hypertensive microvascular changes. Among the evaluated indices: RI, PI and D, the RI appears to be the most reliable indicator. It may serve as a valuable non-invasive marker for detecting hypertensive microvascular changes in the eye by combining both high sensitivity

and acceptable specificity. This highlights the important function of ocular Doppler ultrasound in cardiovascular risk assessment and supports its integration into broader screening strategies.

Presented study reveals a significant variation in BMI between people with hypertension and those without, with hypertensive participants exhibiting a higher mean BMI (32.6 ± 7.2) compared to normotensive individuals (28.9 ± 3.8). This difference was statistically significant ($p < 0.001$), highlighting the well-documented association between excess body weight and hypertension. Obesity is a main risk factor for hypertension due to its impact on vascular resistance, endocrine system stimulation and dysregulation of the renin-angiotensin-aldosterone system.[14]

The systemic microvasculature's structure and function are greatly impacted by systemic hypertension, including the retinal arteries and it is believed that these microvascular changes are the key pathological characteristic of hypertension.[15] With recent advances in imaging techniques, the colour Doppler imaging (CDI) enables the evaluation of retinal vascular hemodynamics, providing details about vascular and morphologic conditions like hypertension.

The CRAs illustrate the structural benefits of peripheral arteries for Doppler flow detection due to multiple anatomical and physiological factors. These include absence of ultrasonic-attenuating structures like bony and fatty tissue, the eyeball's good sonolucency and the OA's near-vertical orientation to the ultrasound transducer which optimises signal acquisition and flow detection.[4] In this study few Doppler indices of the CRA are studies for comparison between hypertensive and non-hypertensive patients which are (PSV, EDV, RI, PI) and the CRA dimeter.

Although both PSV and EDV in hypertensive adults were lower than normotensive one but they show statistically not significant differences ($p = 0.122$, $p = 0.05$), respectively. This disagrees with previous studies who proved that both parameters significantly lower in hypertensive adults like Adenigba et al and Akal et al.[7, 16] However, other studies found that changes in both PSV and EDV affected duration of hypertension and type of treatment significantly. A study by Yilmaz Ovali et al,[17] demonstrated increase in EDV in hypertensive adults. Certain blood pressure lowering medications can increase EDV in hypertensive adult as proved by Ahmetoğlu et al.[18]

In contrast to PSV and EDV, which vary with Doppler angle, the RI value has the advantage of being independent of Doppler angle. It has been found that the RI of the CRA is significantly increased in patients with known hx of hypertension compared with the control study; this is due to increase in the vascular impedance due to stiff vascular wall, this result is consistent with many studies.[4, 18-20] The hallmark of hypertension is increased the peripheral vascular resistance including the retinal arteries, leading to increased PI of the CRA as the result of this study which is the same result of Reddy et al.[4] In contrast to study done in Nigeria by Adenigba et al which state that's no significant increase in PI in hypertensive patients compared with the control group.[7] The discrepancies between this study and presented current investigation may be the result of variations in the study design, sample size and population dynamics. Based on the fact that's hypertension cause decreased arterial lumen at an early stage due to vasoconstriction and due to intima-media thickening and arteriosclerosis superadded by advanced age in the late phase, the result of the current study is significantly decreased CRA lumen in the hypertensive group compared with the control. This is in line with a study done by Kannenkeril et al.[21]

Many arteries are used as markers in literatures to monitor or detect certain diseases, as the carotid artery, which is used as a marker to monitor the insulin sensitivity in polycystic ovary syndrome patients.[22] In presented study, of three Doppler parameters, RI showed the highest diagnostic performance with an AUC of 0.837 (95 % CI: 0.755–0.918, $p < 0.001$), indicating excellent discriminative ability. At a cutoff of 0.635, it achieved a sensitivity of 88.3 % and specificity of 70 %, suggesting it is a strong candidate as a screening tool for early hypertensive microvascular alterations in the eye.

The main limitations of the study are the small population size and unicentre design. In addition, the duration of hypertension and the type of treatment were not studied, which may affect the type of vascular changes differently. Future researches with a multi-centre approach, large sample size, incorporating additional retrobulbar arteries and other confounders like DM and vascular diseases and correlation of the stage of hypertensive retinopathy with the retrobulbar arteries Doppler indices, are recommended to enhance the validity of the results.

Conclusion

CRA Doppler indices demonstrate significant predictive value for hypertensive microvascular changes. Among them, RI exhibited the highest diagnostic accuracy. It may serve as a reliable, excellent marker for early detection of hypertensive microvascular changes.

Ethics

The study was approved by Ethics Committee of Al-Kindy College of Medicine, University of Baghdad, Baghdad, Iraq, the ethical approval decision No 218, dated 27 June 2024.

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None.

Conflicts of interest

The authors declare that there is no conflict of interest.

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Data access

The data that support the findings of this study are available from the corresponding author upon reasonable individual request.

Author ORCID numbers

Shaymaa Khalid Abdulqader (SKA):
0000-0001-7029-0451
Lubna Hasan Najm (LHN):
0009-0001-2838-5761
Noor Yousif Abed (NYA):
0009-0001-0245-372X
Nabeeha Najatee Akram (NNA):
0000-0001-8964-8943

Author contributions

Conceptualisation: SKA, LHN, NYA, NNA
Methodology: SKA, LHN, NYA, NNA
Formal analysis: SKA, LHN, NYA, NNA
Investigation: SKA, LHN, NYA, NNA
Data curation: SKA, LHN, NYA, NNA
Writing - original draft: SKA, LHN, NYA, NNA
Writing - review and editing: SKA, LHN, NYA, NNA

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