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Association of Hypertension with White Matter Changes in MRI in Elderly Patients

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ABSTRACT

Background: In older adults, hypertension significantly contributes to small vessel disease associated with the brain, and it often leads to a structural alteration of the brain that can be seen on MRI scans. Chronic hypertension results in white matter hyperintensities, lacunar infarcts, and brain atrophy that can be sustained and consequently lead to impairments in cognitive and functional ability. To assess the association between hypertension and white matter changes observed in MRI scans of elderly patients.

Methods: This cross-sectional study was carried out in the Medicine Department of Saidu Teaching Hospital, Swat, from Janurary 3rd to July 5th, 2024. A total of 249 elderly patients aged 60 years and older undergo MRI brain imaging. Demographic, clinical, and radiological information were collected through a well designed questionnaire. White matter changes were evaluated with the use of the Fazekas scale. Chi-square tests and binary logistic regression were used to find statistically significant associations with p value under 0.05.

Results: White matter hyperintensities were found among 73.1% of the study. The prevalence was marked among hypertensive patients (86.6%) as opposed to non-hypertensives (47.1%). Hypertensive patients had higher Fazekas scores, more lacunar infarcts, and greater brain atrophy. Logistic regression analysis showed that hypertension, older age, and poorly controlled blood pressure were the most important predictors of changes in white matter.

Conclusion: This investigation observed a significant correlation linking hypertension with structural brain abnormalities in older patients. These results highlight the necessity for timely intervention and control of hypertension to reduce the likelihood of cognitive deterioration in this group of people.

Keywords: Hypertension, White Matter Hyperintensities, Elderly, MRI Brain, Cerebral Small Vessel Disease, Fazekas Score, Cognitive Decline

INTRODUCTION

Chronic Hypertension is one of the most prevalent conditions found in elderly patients all over the globe. It causes considerable impairment of vascular tissues not just in the heart and kidneys, but in the brain as well, where it serves as a major contributor to small vessel disease (1). During proper imaging techniques, elderly patients have been noted to have white matter hyperintensities (WMHs), an abnormality found in striatal, periventricular and deep white matter regions. These changes have been associated with cognitive decline, mobility impairment, and elevated chances of suffering a stroke (2, 3).

The impact of hypertension-related neurological changes is increasingly becoming a public health problem particularly in some low and middle income regions with diagnostic and preventive healthcare deficits as they age (4-6). While almost universally accepted, the existence of white matter alterations as a sign of aging is now presumed to have certain manageable vascular risk determinants' to imply established and chronic long-standing hypertension (7, 8).

There remains a significant gap in the existing evidence with regard to the volume of white matter changes suffered by elderly hypertensive patients in our region, even with growing awareness of the issue. This understanding is critical for timely intervention to avert protracted neurological damage. This study was therefore conducted to evaluate the association between hypertension and white matter changes detected by MRI among elderly patients presenting to a tertiary care hospital.

Methodology

The purpose of this research was to describe a cross-sectional study focused on hypertension and its relationship to white matter changes seen in MRI in older patients. This was done at the Department of Medicine in Saidu Teaching Hospital in Swat District of Khyber Pakhtunkhwa Pakistan. This study was conducted over a period of six months commencing from 3rd January 2024 and broader analyses were completed on 5th July 2024. The research was approved by the Institutional Ethical Review Committee of Saidu Teaching Hospital. Legal guardians of all participants consented and signed the Informed Consent Document prior to participation in the study. Anonymity was ensured throughout the research period and the study adhered to the principles stated in the Helsinki declaration.

The technique of sampling used was consecutive non-probability sampling. Patients who qualified and came forward within the research duration were included until the desired sample size was met.

The sample size was calculated using the WHO Epi Info™ StatCalc tool for a population survey. An expected frequency of white matter changes among hypertensive elderly patients was assumed to be 80%**,** based on findings from previous literature (9). With a confidence level of 95% and an acceptable margin of error of 5%**,** the required sample size was calculated to be 246. To account for possible data loss or non-responses, the final sample size was increased to 249 participants**.**

Participants were included in this study if they were 60 years and older and had a brain MRI done in the selected time frame. Patients with and without hypertension were included. Hypertension status was assessed based on a physician's diagnosis, history of antihypertensive medication, and blood pressure levels according to the acceptable standard. Exclusion criteria consisted of any known neurodegenerative sicknesses like Alzheimer's or Parkinsons disease along with other brain tumors, significant head trauma, major intracranial infections recently or any reasons for not undergoing MRI because of a pace maker or other contraindications.

Data were collected through a structured data collection form. Each participant's demographic details, medical history, and comorbid conditions such as diabetes mellitus, hyperlipidemia, history of stroke or TIA, smoking status, and body mass index were recorded. Blood pressure readings were taken on two separate occasions using a standard mercury sphygmomanometer. Patients with average readings of ≥140/90 mmHg or those on antihypertensive medication were classified as hypertensive. Blood glucose and lipid profiles were obtained from hospital records if available or ordered as needed to confirm comorbid status.

All participants underwent MRI brain scanning using a 1.5 Tesla machine available at the hospital's radiology department. Imaging sequences included T1-weighted, T2-weighted, FLAIR (fluid-attenuated inversion recovery), and susceptibility-weighted imaging. White matter hyperintensities (WMHs) were evaluated using the Fazekas scale, which scores periventricular and deep white matter changes separately from 0 to 3. Radiological findings were interpreted independently by two qualified radiologists to reduce interobserver bias. In cases of discrepancy, a third senior radiologist reviewed the scans to reach a consensus.

To ensure the reliability of data collection, the research team underwent a two-day training session prior to data collection to standardize procedures. Data forms were double-checked by two investigators to ensure completeness and consistency. Internal validity was maintained by applying strict inclusion and exclusion criteria, and using standardized MRI protocols. External validity was supported by including a broad spectrum of elderly patients typical of a secondary care public hospital setting.

All data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25. Descriptive statistics were used to summarize the data. Quantitative variables such as age and BMI were presented as mean and standard deviation, while categorical variables like gender, hypertension status, smoking, diabetes, and MRI findings were expressed as frequencies and percentages. The association between hypertension and white matter changes was assessed using the chi-square test for categorical variables. A p-value of less than 0.05 was considered statistically significant. To identify independent predictors of white matter hyperintensities, binary logistic regression analysis was performed, adjusting for potential confounders such as age, diabetes, smoking, and lipid profile. Results were reported as adjusted odds ratios with 95% confidence intervals.

Result

'The study included a total of 249 elderly patients, most of whom were in the 60–69 age group (41%), followed closely by those aged 70–79 (39%), while a smaller proportion were aged 80 years or above'. Males slightly outnumbered females, comprising 58.2% of the participants. In terms of body mass index, a considerable portion of the population fell into the overweight category (42.6%), with 21.7% classified as obese. Regarding smoking status, nearly one-third of the participants were active smokers, indicating a potentially relevant vascular risk factor. Educational status revealed that the majority had either no formal education or only primary to secondary schooling, with only one-fifth having attained graduation or higher education levels. These baseline demographics help in contextualizing the patient population and their risk profiles.

Table 1: Demographic Characteristics of Participants (n = 249)

Variable	Frequency (n)	Percentage (%)
Age (years)		
60–69	102	41.0
70–79	97	39.0
≥80	50	20.0
Gender		
Male	145	58.2
Female	104	41.8
BMI Category		
Normal (18.5–24.9)	89	35.7
Overweight (25–29.9)	106	42.6
Obese (≥30)	54	21.7
Smoking Status		

Non-smoker	172	69.1
Smoker	77	30.9
Education Level		
Illiterate	96	38.6
Primary/Secondary	103	41.4
Graduate & Above	50	20.0

Hypertension was present in a significant portion of the study population, affecting approximately 65.9% of the participants. Among these, nearly half had been hypertensive for less than five years, while 17% had a history extending beyond a decade. Notably, over half of the hypertensive patients had poorly controlled blood pressure, suggesting inadequate long-term management. Diabetes mellitus was present in 39.4% of the population, and one-third were diagnosed with hyperlipidemia. A history of cerebrovascular events, including stroke or TIA, was documented in 18.1% of the patients. Cognitive impairment, as identified through clinical assessment or MMSE scores below 24, was observed in around one-fourth of participants. These findings highlight a high burden of vascular risk factors, especially among hypertensive individuals, which may contribute to cerebral changes observable on MRI.

Table 2: Clinical Characteristics and Comorbidities

Variable	**Frequency (n)**	**Percentage (%)**
Hypertension		
Yes	164	65.9
No	85	34.1
Duration of Hypertension		
<5 years	78	47.6
5–10 years	58	35.4
>10 years	28	17.0
Blood Pressure Control		
Well-controlled	68	41.5
Poorly-controlled	96	58.5
Diabetes Mellitus		
Yes	98	39.4
No	151	60.6
Hyperlipidemia		
Yes	83	33.3
No	166	66.7

History of Stroke/TIA		
Yes	45	18.1
No	204	81.9
Cognitive Impairment (MMSE <24)	64	25.7

MRI evaluation revealed that white matter hyperintensities were present in 73.1% of the elderly participants, indicating a strong prevalence of small vessel disease-related changes. The Fazekas scoring system was used to assess the severity of deep white matter hyperintensities, with the largest group showing mild changes (score 1), while about 12% demonstrated severe white matter involvement. Periventricular areas were the most common site for these lesions, followed by deep white matter and subcortical/global involvement. Other radiological findings included lacunar infarcts in 17.3% of cases, cerebral microbleeds in 11.2%, and varying degrees of brain atrophy in nearly one-third of the participants. These structural abnormalities support the notion of chronic vascular pathology, which is prevalent in the aging population, especially in the presence of comorbidities like hypertension.

Table 3: MRI Findings (White Matter Changes and Related Features)

MRI Variable	**Frequency (n)**	**Percentage (%)**
White Matter Hyperintensities (WMHs)		
Present	182	73.1
Absent	67	26.9
Fazekas Score (Deep WMH)		
0 (None)	67	26.9
1 (Mild)	94	37.8
2 (Moderate)	58	23.3
3 (Severe)	30	12.0
Location of WMHs		
Periventricular	116	63.7
Deep White Matter	47	25.8
Subcortical/Global	19	10.4
Lacunar Infarcts	43	17.3
Microbleeds	28	11.2
Brain Atrophy	71	28.5

When comparing hypertensive and non-hypertensive participants, a statistically significant difference was observed in the frequency and severity of white matter changes. White matter hyperintensities were identified in 86.6% of hypertensive patients, compared to only 47.1% of their non-hypertensive counterparts. Similarly, higher Fazekas scores (≥ 2) were more common in the hypertensive group, indicating greater lesion burden. Lacunar infarcts and brain atrophy also showed higher occurrence in patients with hypertension. While microbleeds were more frequently seen in hypertensive individuals, this finding did not reach statistical significance. Overall, hypertension emerged as a strong correlating factor with the presence and severity of white matter abnormalities on MRI.

Table 4: Association of Hypertension with White Matter Changes

White Matter Changes	Hypertensive (n=164)	Non-Hypertensive (n=85)	p-value
WMHs Present	142 (86.6%)	40 (47.1%)	**<0.001**
Fazekas Score ≥2	68 (41.5%)	20 (23.5%)	**0.008**
Lacunar Infarcts Present	37 (22.6%)	6 (7.1%)	**0.002**
Microbleeds Present	22 (13.4%)	6 (7.1%)	**0.112**
Brain Atrophy Present	54 (32.9%)	17 (20.0%)	**0.038**

Statistical test used: Chi-square test

Multivariate logistic regression analysis was performed to identify independent predictors of white matter hyperintensities. Increasing age, especially those aged 70 and above, was associated with a twofold increase in the likelihood of developing these changes. Hypertension was the most powerful predictor, with affected individuals being over four times more likely to exhibit white matter hyperintensities. Diabetes mellitus and poorly controlled blood pressure were also significant contributors. Interestingly, variables such as current smoking and obesity did not show a statistically significant association in the adjusted model. These results reaffirm the pivotal role of vascular health in maintaining cerebral integrity in the elderly and underscore the importance of effective hypertension management.

Table 5: Binary Logistic Regression – Predictors of White Matter Hyperintensities

Variable	Adjusted Odds Ratio (AOR)	95% CI	p-value
Age ≥70 years	2.21	1.18–4.12	**0.013**
Hypertension	4.67	2.52–8.66	**<0.001**
Diabetes Mellitus	1.98	1.05–3.74	**0.034**
Poor BP control	2.83	1.44–5.55	**0.002**
Smoking (Current)	1.49	0.81–2.75	0.198
Obesity (BMI ≥30)	1.17	0.58–2.35	0.656

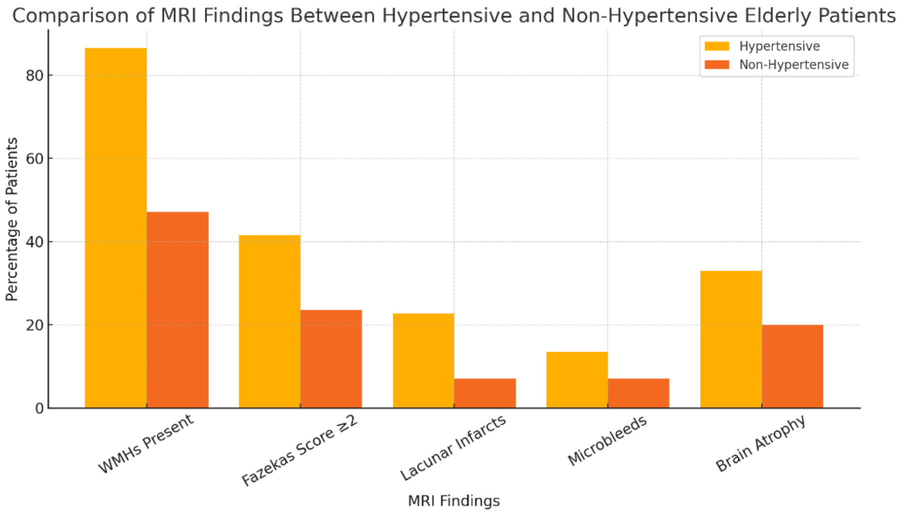

Figure 1: The graph shows that elderly patients with hypertension had a higher frequency of white matter changes on MRI compared to those without hypertension. White matter hyperintensities, higher Fazekas

scores, lacunar infarcts, and brain atrophy were all more common in the hypertensive group. Microbleeds showed a slight increase but with less difference between the two groups. These findings highlight the link between hypertension and brain structural changes in the elderly.

Discussion

This study explored the relationship between hypertension and white matter changes in elderly individuals using brain MRI. The findings revealed a strong association between elevated blood pressure and the presence of white matter hyperintensities, particularly among those with long-standing or poorly controlled hypertension. These results align with previous studies that have identified hypertension as a key contributor to small vessel disease and age-related changes in brain structure (10-12).

In our population, white matter hyperintensities were present in more than 70 percent of elderly patients, with significantly higher rates among those with hypertension. These findings were consistent with the Rotterdam Scan Study, which reported a very high prevalence of white matter lesions in individuals aged 60 years and older, with hypertension being a major risk factor (13-15). Similarly, the 'Atherosclerosis Risk in Communities (ARIC) studies found that both systolic and diastolic hypertension were associated with increased burden of white matter abnormalities over time, supporting the hypothesis that chronic vascular injury leads to progressive white matter damage' (16, 17).

The distribution and severity of these lesions, as reflected by higher Fazekas scores among hypertensive participants, further suggest that long-standing hypertension accelerates small vessel pathology in the brain. Previous MRI-based research has shown that elevated blood pressure contributes to arteriolosclerosis and chronic hypoperfusion, both of which are implicated in the pathogenesis of white matter changes (6, 18, 19). Our study also found a higher incidence of lacunar infarcts and brain atrophy in hypertensive patients, which may represent more advanced stages of cerebral small vessel disease(20).

Interestingly, while microbleeds were more frequent in hypertensive patients, 'the difference was not statistically significant'. This may be due to the relatively lower sensitivity of the imaging sequence used or the small number of cases. Nonetheless, previous literature has also suggested that cerebral microbleeds are linked to hypertension, particularly in deep brain structures, and their presence may indicate more severe vascular pathology (21, 22).

The logistic regression model in our study identified hypertension as the most significant independent predictor of white matter changes, even after adjusting for age, diabetes, and other confounders. Age was also a strong predictor, as expected, given the cumulative vascular burden with aging. Diabetes mellitus and poorly controlled blood pressure were additional contributors. These observations highlight the multifactorial nature of white matter injury in the elderly, where vascular risk factors interact and compound the effects on brain tissue.

Our findings have important clinical implications. Given the high burden of white matter abnormalities among hypertensive elderly individuals, early identification and aggressive management of blood pressure may help slow down the progression of cognitive and neurological decline. Brain MRI can 'serve as a useful tool in assessing subclinical cerebrovascular disease in patients at risk'.

While the study provides valuable insights, it is not without limitations. Being a single-center study, the findings may not be generalizable to other populations. Additionally, due to the cross-sectional design, causality cannot be established. However, the robust sample size, standardized MRI assessment, and use of multivariable analysis strengthen the credibility of the results.

In conclusion, this study reinforces the strong association between hypertension and structural brain changes in the elderly. The occurrence and intensity of white matter hyperintensities, as well as other MRI features such as lacunes and atrophy, were significantly greater in individuals with hypertension. These findings highlight the importance of aggressive management of blood pressure and periodic neurologic examination in older patients to prevent prolonged cognitive and functional deficits.

Conclusion

This research identified a strong link between hypertension and changes in white matter in MRIs of older patients. Patients suffering from hypertension had a greater incidence and degree of white matter hyperintensities, lacunar infarcts, and brain atrophy. The most notable determinants for these changes in the brain were poor blood pressure control and advancing age. This research underscores the necessity of early identification and aggressive treatment of hypertension in the elderly. Such intervention could mitigate the decline in cognitive function and the risk of cerebrovascular events in this population.

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