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Original Research Article **Radiology**

Association between Hypertension Duration and Brain Volume: An MRI-Based Quantitative Analysis

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Abstract

Background: Prolonged hypertension is believed to affect brain structure due to chronic vascular stress. ***Objective:*** To assess the correlation between hypertension duration and changes in brain volumes using 3D MRI. ***Methods:*** This cross-sectional study involved 100 hypertensive individuals aged 30–60 years. Brain volumes (gray and white matter) were measured using 3D MRI. Pearson correlation analysis was used to evaluate associations with hypertension duration. ***Results:*** Strong negative correlations were found between hypertension duration and both gray and white matter volumes ($r = -0.49$ to -0.56, $p < 0.001$). ***Conclusion:*** Longer duration of hypertension is associated with reduced brain volume, reinforcing the need for early detection and sustained management of blood pressure.

Keywords: Hypertension, Brain Volume, MRI, Cerebral Atrophy, Quantitative Analysis.

1. INTRODUCTION

The duration of hypertension may influence the severity of brain structural changes. Prolonged exposure to elevated blood pressure may cause cumulative cerebral damage through mechanisms such as endothelial dysfunction, chronic hypoperfusion, and disruption of the blood–brain barrier. These pathophysiological processes can lead to neuronal loss, white matter lesions, and brain atrophy, even in the absence of clinical symptoms. Advances in neuroimaging, particularly three-dimensional volumetric MRI, have enabled more precise and quantitative assessment of brain morphology, providing valuable insights into the subtle effects of vascular risk factors. Understanding how the chronicity of hypertension relates to brain volume loss is crucial for identifying at-risk individuals early and implementing timely interventions. This study explores the correlation between the duration of hypertension and volumetric parameters of brain tissue using 3D MRI, aiming to highlight the potential neuroanatomical consequences of long-term uncontrolled blood pressure.

2. MATERIALS AND METHODS

This cross-sectional descriptive analytical study included a sample of 100 hypertensive individuals aged between 30 and 60 years. All participants had undergone brain MRI using a 1.5 Tesla Toshiba scanner and had a documented duration of hypertension. The MRI protocol included T1-weighted, T2-weighted, FLAIR, and 3D volumetric sequences, enabling the quantitative assessment of brain tissue compartments, including left and right white matter and gray matter volumes. Participants were included if they had a confirmed diagnosis of hypertension, documented disease duration, and provided informed consent. Individuals were excluded if they had a history of neurodegenerative or psychiatric disorders, traumatic brain injury, congenital brain anomalies, or space-occupying lesions. Poor image quality or missing data also led to exclusion. The primary variables assessed were age, gender, body mass index (BMI), hypertension duration, and brain volume measurements. Pearson correlation analysis was used to evaluate the association between hypertension duration and brain volumetric measures, with statistical significance defined at $p < 0.05$.

3. RESULTS

This study included 152 individuals, of whom 102 (83.6%) were diagnosed with hypertension and 50 (16.4%) served as the control group. Among the control group, 25 participants were male and 25 were female.

Four brain volume measurements were taken for each participant: Left Total White Matter (LTWM), Left Total Gray Matter (LTGM), Right Total White Matter (RTWM), and Right Total Gray Matter (RTGM). Additionally, weight and height were recorded, and Body Mass Index (BMI) was calculated. Age was documented for all participants, and the duration of hypertension (in years) was recorded for those in the hypertensive group.

1 ± 159.67. Among males, the LTWM was 263.41 ± 100.34, compared to 379.64 ± 23.18 in females. The median LTGM was 302.98 ± 86.01, with males showing an average of 298.48 ± 61.31 versus 375.11 ± 19.97 in females. Similarly, RTWM was 284.64 ± 160.37 overall, with a male average of 272.17 ± 100.91 compared to 380.02 ± 22.49 in females. For RTGM, the median was 301.58 ± 89.17, with males averaging 299.10 ± 62.49 and females 377.89 ± 20.14.

Table 1: Presents the characteristics of the sample and compares the brain volume measurements between males and females

	Overall sample		**Male**		**Female**	
	Median	**IQR**	**Median**	**IQR**	**Median**	**IQR**
LT WM	282.31	159.67	263.41	100.34	379.64	23.18
LT GM	302.98	86.01	298.48	61.31	375.11	19.97
RT WM	284.64	160.37	272.17	100.91	380.02	22.49
RT GM	301.58	89.17	299.10	62.49	377.89	20.14
BMI	28.44	6.90	28.33	6.26	29.72	8.51
Age (yrs)	47	17	47	17	43	17
Total (%)	**152 (100%)**		**127 (83.6%)**		**25 (16.4%)**	

3.1 Correlation Between Duration and Brain Volumes:

Table 2: Correlation between Duration of Hypertension and Brain Volumes

Variable	**Correlation Coefficient (r)**	**P-value**
Left White Matter (WM)	-0.496	0.000
Left Gray Matter (GM)	-0.556	0.000
Right White Matter (WM)	-0.490	0.000
Right Gray Matter (GM)	-0.564	0.000

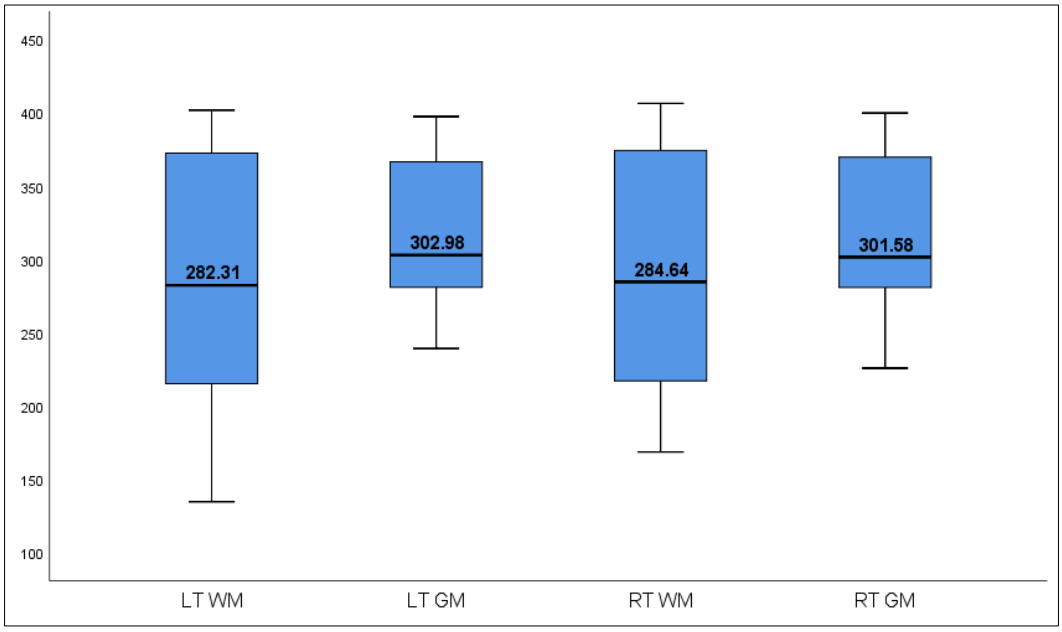

Figure 1: Present the comparison of brain volume measurements in all sample

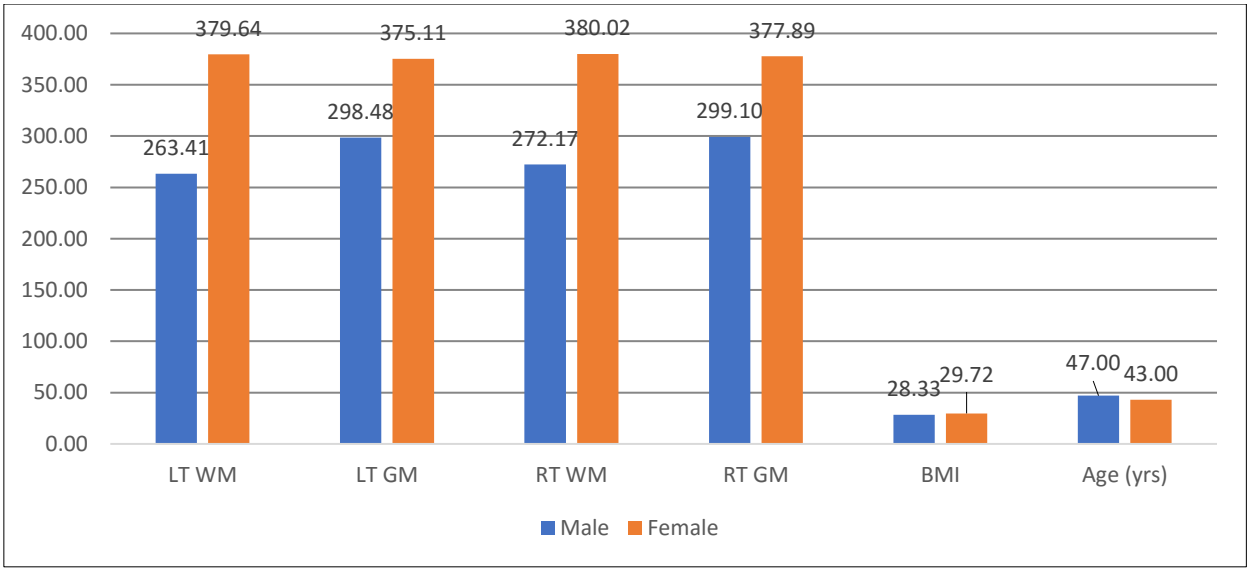

Figure 2: Comparison between male and female participants, indicating consistently higher values across all brain volume parameters in females

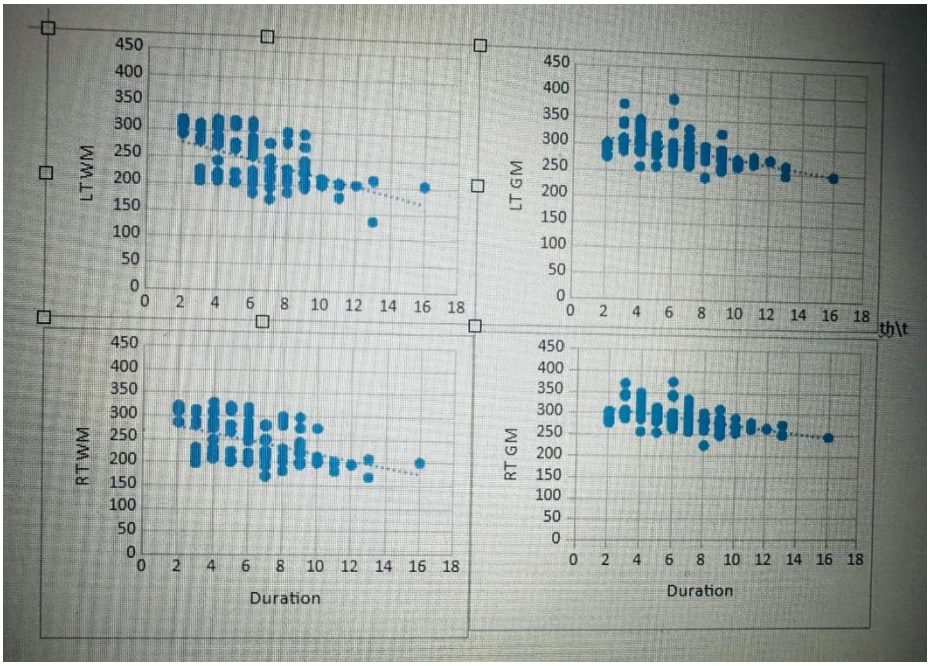

Figure 3: Presents scatter plots depicting these negative correlations

4. DISCUSSION

This study reveals a significant inverse correlation between the duration of hypertension and brain volumes—specifically in both gray and white matter. The results suggest that the longer an individual lives with hypertension, the greater the degree of brain atrophy. These findings align with previous research linking chronic high blood pressure with neurodegeneration, reduced cerebral perfusion, and brain tissue loss.

Importantly, the strength and consistency of the correlation across both hemispheres (left and right) and both tissue types (white and gray matter) point toward a diffuse and progressive impact of hypertension on the brain. The use of 3D volumetric MRI enhances the precision of brain volume assessments, providing robust quantitative evidence of structural deterioration associated with prolonged hypertension.

Despite these significant findings, the study is limited by its cross-sectional nature, which precludes establishing causality. Additionally, potential confounding factors such as medication type, treatment adherence, comorbidities (e.g., diabetes), and lifestyle variables were not controlled. Future longitudinal studies with comprehensive clinical profiling are needed to confirm these associations and identify possible protective interventions.

5. CONCLUSION

Prolonged hypertension is associated with progressive reductions in both gray and white matter volumes, suggesting an adverse effect on global brain structure. These volumetric reductions may contribute to future cognitive impairment and increased dementia risk. Early identification and sustained control of blood pressure should be emphasized as a strategy to protect brain health and reduce the burden of cerebrovascular and neurodegenerative diseases

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