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The Predictive Value of Aortic Stiffness Index for Stroke Severity in Patients with Acute Ischemic Stroke

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ABSTRACT

Background: Stroke severity significantly influences clinical outcomes in acute ischemic stroke patients. The arterial stiffness index (ASI) is a potential predictor of stroke severity, though its clinical value requires further investigation.

Objective: This study aimed to estimate the predictive value of ASI for stroke severity in patients with acute ischemic stroke and to examine its relationship with other clinical variables.

Patients and methods: This cross-sectional study included 120 patients hospitalized for acute ischemic cerebrovascular disease within 24 hours. Patients were divided into two groups based on National Institutes of Health Stroke Scale (NIHSS) scores: Group 1 (NIHSS < 16, n=78) and group 2 (NIHSS ≥ 16, n=42). Data on demographics, risk factors, and clinical variables were collected. Echocardiographic analysis was used to calculate ASI. Primary outcomes included the predictive value of ASI for stroke severity, and secondary outcomes were hospital length of stay and 28-day mortality.

Results: Group 2 patients were older (64.1 ± 5.13 vs. 60.6 ± 6.08 years, p=0.002). Diabetes mellitus (69% vs. 41%, p=0.003) and dyslipidemia (57.1% vs. 35.9%, p=0.025) were more prevalent in group 2. Higher systolic (177.6 ± 10.23 mmHg vs. 170.3 ± 19.78 mmHg, p=0.04) and diastolic blood pressure (91.1 ± 9.14 mmHg vs. 86.5 ± 9.13 mmHg, p=0.01) were observed in group 2. ASI was significantly higher in group 2 (3.76 ± 0.17 vs. 3.10 ± 0.20, p<0.001). Multivariate analysis identified ASI as an independent predictor of stroke severity (OR 1.84, 95% CI 1.35-2.51, p<0.001). Mortality (26.2% vs. 7.7%, p=0.006) and hospital stay (11.8 ± 4.68 vs. 7.28 ± 3.17 days, p=0.001) were higher in group 2.

Conclusion: ASI is a significant predictor of stroke severity in acute ischemic stroke patients, correlating with worse clinical outcomes.

Keywords: Acute ischemic stroke, Arterial stiffness index, Stroke severity, NIHSS, Echocardiography.

INTRODUCTION

Stroke is a leading cause of mortality and long-term disability worldwide, with acute ischemic stroke accounting for the majority of cases. The severity of a stroke is a critical factor in determining patient outcomes, influencing both immediate clinical decisions and long-term prognosis. Identifying reliable predictors of stroke severity can significantly enhance early intervention strategies and improve patient management [1].

Arterial stiffness, a marker of vascular health, has gained attention for its potential role in cerebrovascular diseases. The arterial stiffness index (ASI) is a non-invasive measure that reflects the elasticity of the arterial walls. Increased arterial stiffness has been associated with higher cardiovascular risk and adverse events. Previous studies have suggested that arterial stiffness could be linked to stroke severity, but the relationship remains underexplored, particularly in the acute phase of ischemic stroke [2].

Accurate prediction of stroke severity using ASI could provide clinicians with valuable insights into the expected course of the disease, enabling more targeted and effective treatment strategies. By integrating ASI measurement into the initial assessment of stroke patients, healthcare providers might be able to stratify patients based on their risk and tailor interventions accordingly [3, 4].

Therefore, the present study aimed to estimate the predictive value of the ASI and its relation to stroke severity in subjects with acute ischemic stroke. Additionally, the study sought to evaluate the relationship between ASI and other clinical variables, potentially offering new avenues for improving stroke management and patient outcomes.

PATIENTS AND METHODS

This cross-sectional study included 120 patients hospitalized for acute ischemic cerebrovascular disease within the first 24 hours. According to NIHSS, patients were classified into two groups; Group 1 included 78 cases (65%) with scores less than 16, and group 2 that included 42 patients (35%) with score higher than 16. Patients were recruited and assessed for eligibility from the Department of Critical Care Medicine, Benha University Hospitals. The study was done from January 2022 to June 2023.

Inclusion criteria: Adult patients aged 18-70 years old who were hospitalized for acute ischemic cerebrovascular disease (within the first 24 hours).

Exclusion criteria: Patients with any previous history of cerebrovascular disease or transient ischemic attack, cerebral haemorrhage, presence of atrial fibrillation, coronary heart disease, left ventricular systolic dysfunction, severe valvular heart disease, chronic pulmonary disease, chronic renal failure, congenital heart disease. Patients in whom a proper position could

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not be obtained echocardiographic examination and those with improper echocardiographic image analysis.

Diagnosis of acute ischemic stroke was based on clinical characteristics and cranial imaging, following American Heart Association/American Stroke Association guidelines. Baseline demographics (age, sex, BMI) and traditional risk factors (hypertension, diabetes, dyslipidemia, smoking) were recorded. All patients underwent immediate CT scans upon admission, with troponin levels and ECG taken post-hospitalization.

NIHSS scores were calculated on admission. Transthoracic echocardiographic analyses were performed according to American Society of Echocardiography guidelines, and ASI was calculated.

Outcomes: Primary outcomes were estimating the predictive value of ASI in relation to the stroke severity that was determined by NIHSS score in patients with acute ischemic stroke. Secondary outcomes were the estimation of hospital length of stay and 28 days mortality.

Ethical consideration: The study was approved by The Research Ethics Committee, Benha University. All patients provided written informed consents prior to their enrolment. The consent form explicitly outlined their agreement to participate in the study and for the publication of data, ensuring protection of their confidentiality and privacy. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical analysis of data:

The collected data were statistically analyzed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Categorical variables were represented as numbers and percentages, while continuous variables were shown as mean and standard deviation. Appropriate statistical tests, including Student's t-test, Mann–Whitney U test, and Chi-square test, were employed for data comparisons. Statistical significance was determined at $p \leq 0.05$. Pearson's or Spearman's correlation was utilized to assess the relationship between NIHSS scores and other echocardiographic parameters. Multivariate logistic regression analysis was conducted to explore the correlation between NIHSS scores and clinical parameters and to predict the value of ASI concerning stroke severity.

RESULTS

As shown in table (1), the mean age of the included cases was 60.6 and 64.1 years in groups 1 and 2 respectively, with a significant increase in group 2 (p = 0.002). There was no significant difference between the two groups regarding gender distribution and BMI.

Table (1): Analysis of the demographic data according to the NIHSS score

Variable	Group 1 (NIHSS score < 16) (N= 78)	Group 2 (NIHSS score ≥ l6) (N= 42)	Test of sig.
Age (years)	60.6 ± 6.08	64.1 ± 5.13	t = - 3.11 **P = 0.002***
Males	43 (55.1%)	27 (64.3%)	χ^2= 0.942 P = 0.332
Females	35 (44.9%)	15 (35.7%)	
BMI (Kg/m^2)	27.95 ± 3.20	28.29 ± 3.19	t = - 0.565 P = 0.573

BMI: body mass index. *: Statistically significant (P< 0.05).

As shown in table (2), there was a statistically significant increase in the prevalence of diabetes mellitus and dyslipidaemia among patients in group 2 compared to group 1.

Table (2): Analysis of the associated diseases/risk factors according to the NIHSS score

Variable	Group 1 (NIHSS score < 16) (N= 78)	Group 2 (NIHSS score ≥ l6) (N= 42)	Test of sig.
Hypertension	24 (30.8%)	18 (42.9%)	χ^2= 1.753 P = 0.185
Diabetes mellitus	32 (41%)	29 (69%)	χ^2= 8.577 **P = 0.003***
Dyslipidemia	28 (35.9%)	24 (57.1%)	χ^2= 5.018 **P = 0.025***
Smoking	9 (11.5%)	8 (19%)	χ^2= 0.272 P = 0.602

*: Statistically significant (P< 0.05).

As shown in table (3), systolic and diastolic blood pressure measurements and HR showed a significant increase in high-risk patients.

Table (3): Analysis of the blood pressure and heart rate according to NIHSS score

Variable	Group 1 (NIHSS score < 16) (N= 78)	Group 2 (NIHSS score ≥ l6) (N= 42)	Test of sig.
SBP (mmHg)	170.3 ± 19.78	177.6 ± 10.23	t = 2.11 **P = 0.04***
DBP (mmHg)	86.5 ± 9.13	91.1 ± 9.14	t = - 2.57 **P = 0.01***
HR (B/min)	88.92 ± 9.69	93.81 ± 10.11	t = - 2.596 **P = 0.011***

SBP: systolic blood pressure. DBP: diastolic blood pressure. HR: heart rate. *: Statistically significant (P< 0.05).

As shown in table (4), all of the measured laboratory markers showed a significant rise in the high-

risk group, apart from HDL, that showed a significant decline.

Table (4): Analysis of the laboratory data according to NIHSS score

Variable	Group 1 (NIHSS score < 16) (N= 78)	Group 2 (NIHSS score ≥ l6) (N= 42)	Test of sig.
RBG (mg/dl)	172.6 ±28.3	184.5 ± 20.7	t = -2.41 **P = 0.02**
HBA1c (%)	8.12 ± 1.26	8.66 ± 0.81	t = 2.52 **P = 0.01***
LDL (mg/dl)	115.83 ± 21.23	131.52 ± 18.50	t = -3.034 **P = 0.012***
HDL (mg/dl)	44.90 ± 8.04	37.17 ± 7.85	t = - 2.856 **P = 0.030***
Troponin (ng/L)	6.47 ± 1.96	13.91 ± 3.01	t = - 16.653 **P < 0.001***

HbA1c: glycated hemoglobin. HDL: high density lipoprotein. LDL: low density lipoprotein. RBG: random blood glucose. *Significant at p<0.05.

As shown in table (5), some echocardiographic parameters showed significant differences between the two groups.

Table (5): Analysis of the echocardiographic parameters according to the NIHSS score

Variable	Group 1 (NIHSS score < 16) (N= 78)	Group 2 (NIHSS score ≥ l6) (N= 42)	Test of sig.
LV septal thickness (mm)	11.04 ± 1.63	11.8 ± 1.29	t = - 2.13 **P = 0.035***
LVDd (mm)	51.61 ± 5.68	53.88 ± 6.26	t = -1.96 P = 0.05
LV posterior wall thickness (mm)	10.81 ± 1.42	11.5 ± 1.69	t = - 2.43 **P = 0.02***
LVDs (mm)	40.64 ± 4.25	41.95 ± 4.50	t = -1.63 P = 0.107
LVEDV (ml)	83.4 ± 10.35	84.99 ± 14.8	t = - 0.615 P = 0.543
LVESV (ml)	40.9 ± 6.68	42.6 ± 5.43	t = - 1.38 P = 0.170
LAD (mm)	40.74 ± 8.70	44.91 ± 8.31	t = -2.543 **P = 0.012***
RAD (mm)	33.45 ± 3.12	33.6 ± 4.39	t = -0.245 P = 0.821
RVDd (mm)	29.2 ± 1.95	30.7 ± 2.57	t = - 1.78 P < 0.310
LVEF (%)	59.83 ± 6.35	54.8 ± 9.39	t = 3.42 **P = 0.005***
ASI	3.10 ± 0.20	3.76 ± 0.17	t = - 8.014 **P < 0.001***

ASI: Aortic stiffness index.

As shown in table (6), mortality rate and hospitalization showed a significant rise in high-risk patients.

Table (6): Analysis of the outcomes according to the NIHSS score

Variable	Group 1 (NIHSS score < 16) (N= 78)	Group 2 (NIHSS score ≥ l6) (N= 42)	Test of sig.
Mortality	6 (7.7%)	11 (26.2%)	χ^2 = 7.682 **P = 0.006***
Hospital stay (Days)	7.28 ± 3.17	11.8 ± 4.68	MW= 5.72 **P = 0.001***

DISCUSSION

The present study revealed that the mean age of patients was 61.8 ± 5.98 years, with 58.3% being men and a mean BMI of 28.06 ± 3.17 kg/m². These findings align with **Khan *et al.'s*** [5] study on 104 ischemic stroke patients, where 57.69% were males, the mean age was 53.09 ± 12.51 years, and the mean BMI was 27.54 ± 3.03 kg/m². **Öztürk *et al.*** [6] also reported older mean ages in patients with higher NIHSS scores (≥16: 69.8 ± 17.7 years; <16: 65.4 ± 12.7 years).

Diabetes mellitus was the most common comorbidity (50.8%), followed by dyslipidemia (43.3%) and hypertension (35%). Smokers comprised 14.2% of the study population. Similarly, **Khan *et al.*** [5] found dyslipidemia in 39.42% of ischemic stroke patients, with 48.08% having diabetes and 64.42% hypertension. **Gul *et al.*** [7] reported dyslipidemia in 55% of ischemic stroke patients.There was a statistically significant increase in diabetes mellitus and dyslipidemia in group 2 compared to group 1. **Matsuo *et al.*** [8] found that smoking is associated with unfavorable outcomes three months after acute ischemic stroke. **Öztürk *et al.*** [3] reported no significant increase in hypertension, diabetes, and smoking in patients with NIHSS scores ≥16 versus <16. However, **Farooque *et al.*** [9] found no significant association between NIHSS scores and diabetes, dyslipidemia, and hypertension in their study of 141 stroke patients. Group 2 also showed significantly higher SBP, DBP, and HR compared to group 1. These results align with **Öztürk *et al.*** [6] who found that HR, SBP, and DBP were significantly higher in patients with NIHSS scores ≥16.

All measured laboratory markers significantly increased in the high-risk group, except HDL, which significantly declined. Group 2 showed higher RBG, HbA1c, LDL, and troponin levels than in group 1. **Öztürk *et al.*** [6] also reported higher HbA1c, LDL, and troponin levels in patients with NIHSS scores ≥16, while HDL was lower, though was not significant. **Abdi *et al.*** [10] found higher troponin levels in patients with more severe strokes, as measured by NIHSS.

Echocardiographic parameters revealed significant increases in LV septal thickness, LV posterior wall thickness, and LAD in group 2 compared

to group 1, with a significant decrease in LVEF in group 2. **Sharma *et al.* [11]** found that 81% of TTEs in AIS hospitalizations were abnormal, particularly in older patients with coronary artery disease and other conditions. Similarly, **Kim *et al.* [2]** reported that LVEF < 62% and atrioventricular sclerosis were independent predictors of worse cardiovascular outcomes in AIS patients. The risk was markedly higher in patients with both reduced LVEF and AV sclerosis.

The present study revealed the presence of a statistically significant increase in the aortic stiffness index (ASI) among patients in group 2 compared to group 1 (3.76 ± 0.17 vs. 3.10 ± 0.20, respectively, P value < 0.001). Such findings are in agreement with **Öztürk *et al.* [6]** study on 97 adult patients with acute ischemic stroke (≤ 24 hours of symptom beginning) reported that LV wall thickness and ASI values were significantly higher in patients with NIHSS score ≥16 compared with patients with NIHSS score <16. LVEF were significantly lower in patients with NIHSS score ≥16 than in patients with NIHSS score <16. A previous study by **Setyopranoto and Rakhmawati [12]** showed no significant relationship between CIMT and ischemic functional stroke, while a significant relationship was found between aortic diameter and functional stroke (p = 0.013). Additionally, **Wu *et al.* [13]** reported that arterial stiffness mediates the positive association between aging and blood pressure, and arterial stiffness might precede elevated blood pressure.

The present study revealed a statistically significant increase in the mortality rate among patients in group 2 compared to group 1. Furthermore, there was a statistically significant increase in the duration of hospital stay among patients in group 2 compared to group 1. Such results are in agreement with **Demir *et al.* [14]** who studied 107 patients presenting with acute ischemic stroke and demonstrated that for patients who died during hospitalization, NIHSS and Rankin scores were higher than patients who were discharged on admission. Moreover, arterial stiffness parameters of augmentation index and pulse wave velocity (PWV) were significantly higher in patients who died during hospitalization than patients who were discharged. In accordance, **Farooque *et al.* [9]** study on 141 patients admitted within 24 hours of the onset of symptoms of a stroke reported that mortality was significantly associated with NIHSS score categories. There was no mortality in stroke patients with good NIHSS score (n=21/21, 100%) while mortality was observed in a minor proportion (n=4/41, 9.8%) of participants with moderate NIHSS score. In contrast, mortality was observed in the highest proportion (n=54/79, 68.3%) of stroke patients with poor NIHSS score.

Limitations: This study has several limitations. Its cross-sectional design precludes the establishment of causality between ASI and stroke severity. The relatively small sample size and single-center setting may limit the generalizability of the findings. Additionally, potential confounding factors, such as unmeasured comorbidities and variations in treatment protocols, could have influenced the results. Lastly, the study relied on echocardiographic measurements, which can be subject to operator variability. Future studies with larger, multi-center cohorts and longitudinal designs are needed to confirm these findings and explore the underlying mechanisms.

CONCLUSIONS

ASI was significantly higher in patients with severe acute ischemic stroke. The result of the present study suggested that higher ASI is associated with higher NIHSS score (≥16) in patients with acute ischemic stroke and higher mortality rate. The prevalence of hypertension, diabetes mellitus, dyslipidemia and being smoker was higher among patients with higher NIHSS score (≥16).

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