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Left Atrial Remodeling in Embolic Stroke of Undetermined Source: Association with Left Atrial Volume Index

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ABSTRACT

Background: Embolic Stroke of Undetermined Source (ESUS) represents a major subgroup of ischemic stroke in which no definite etiology can be identified despite comprehensive evaluation. Recent evidence suggests that atrial cardiopathy and left atrial structural remodeling may contribute significantly to the pathogenesis of ESUS. Left Atrial Volume Index (LAVI) has emerged as a potential marker of atrial dysfunction and embolic risk.

Objective: To evaluate the association between Left Atrial Volume Index (LAVI) and ischemic stroke subtypes, particularly Embolic Stroke of Undetermined Source (ESUS), and to determine whether ESUS patients demonstrate higher LAVI values compared to non-cardioembolic stroke patients.

Materials and Methods: A hospital-based cross-sectional study was conducted in the Department of General Medicine, from November 2023 to January 2025. A total of 96 ischemic stroke patients aged 18 years and above were enrolled. Detailed clinical assessment, neuroimaging, carotid Doppler, electrocardiography, and transthoracic echocardiography were performed. Left atrial volume was measured using 2D echocardiography and indexed to body surface area to derive LAVI. Patients were classified into cardioembolic stroke, non-cardioembolic stroke, and ESUS groups. Statistical analysis was performed using SPSS version 26.

Results: A total of 96 ischemic stroke patients were included in the study. The mean age was 61.15 ± 14.98 years, with 57.3% of patients aged above 60 years. Males predominated in the study population (64.6%). The mean left atrial volume was 28.22 ± 8.91 mL, while the mean Left Atrial Volume Index (LAVI) was 16.46 ± 5.38 mL/m². Among stroke subtypes, ESUS was the most common (45.8%), followed by non-cardioembolic stroke (37.5%) and cardioembolic stroke (16.7%). ESUS patients demonstrated the highest mean LAVI values (17.46 ± 5.36 mL/m²), compared to cardioembolic (16.90 ± 6.46 mL/m²) and non-cardioembolic stroke patients (15.05 ± 4.70 mL/m²). Although the difference was not statistically significant (p=0.129), ESUS patients showed a trend toward higher atrial remodeling.

Conclusion: The present study showed that ESUS patients had relatively higher Left Atrial Volume Index (LAVI) values compared to non-cardioembolic stroke patients, supporting the possible role of atrial cardiopathy in ESUS. Elevated LAVI in the absence of overt atrial fibrillation suggests that subclinical atrial remodeling may contribute to occult cardioembolic stroke. LAVI may serve as a useful non-invasive marker for stroke risk stratification and further cardiac evaluation.

Keywords: *LAVI, Left Atrial Volume Index, ESUS, Embolic Stroke of Undetermined Source, Ischemic Stroke, Atrial Cardiopathy, Echocardiography.*

INTRODUCTION

Stroke remains one of the leading causes of mortality and long-term disability worldwide. Ischemic stroke accounts for the majority of stroke cases and results from interruption of cerebral blood flow due to arterial occlusion.(1) Despite advances in diagnostic modalities, a significant proportion of ischemic strokes continue to be classified as cryptogenic or embolic stroke of undetermined source (ESUS).(2)

ESUS refers to a non-lacunar ischemic stroke without evidence of significant extracranial or intracranial atherosclerosis, major cardioembolic source, or other specific causes despite thorough evaluation.The concept of ESUS was introduced to identify patients who may harbor occult embolic mechanisms that are not detected during routine workup.(2)

Increasing evidence highlights the importance of atrial cardiopathy in the pathogenesis of ESUS. Structural and functional abnormalities of the left atrium, including atrial fibrosis, dilation, and impaired atrial mechanics, may predispose patients to thromboembolism even in the absence of clinically evident atrial fibrillation.(3)

The Left Atrial Volume Index (LAVI) is an echocardiographic parameter that reflects left atrial size after indexing to body surface area. Elevated LAVI has been associated with atrial fibrillation, diastolic dysfunction, heart failure, and cardioembolic stroke.(3,4) Recent studies have suggested that increased LAVI may also be associated with ESUS and recurrent stroke risk.(5,6)

Given the growing interest in atrial cardiopathy and occult cardioembolism, assessment of LAVI may provide important insights into stroke etiology and risk stratification. This study was undertaken to evaluate the association between LAVI and ischemic stroke subtypes, particularly ESUS.(7,8)

AIM AND OBJECTIVES

Aim

To study the association between Left Atrial Volume Index (LAVI) and Embolic Stroke of Undetermined Source (ESUS).

Objectives

1. To assess Left Atrial Volume Index (LAVI) among patients with ischemic stroke.
2. To compare LAVI among cardioembolic, non-cardioembolic, and ESUS stroke subtypes.
3. To determine whether ESUS patients demonstrate higher LAVI values compared to non-cardioembolic stroke patients.
4. To evaluate the clinical utility of LAVI as a marker of atrial cardiopathy in ischemic stroke.

MATERIALS AND METHODS

Study Area

Department of General Medicine, M S Ramaiah Medical College, Bangalore.

Study Design

Hospital-based cross-sectional study.

Study Duration

August 2023 to January 2025.

Study Population

All ischemic stroke patients aged 18 years and above admitted during the study period.

Sample Size

The sample size was calculated using prevalence estimates from previous literature and was determined to be 96 subjects.

Sampling Method

Convenient sampling.

Inclusion Criteria

- Ischemic stroke patients aged 18 years and above.
- Patients who provided written informed consent.

Exclusion Criteria

- Patients unwilling to participate.
- Hemorrhagic stroke patients.
- Patients with left atrial changes secondary to heart failure.

METHODOLOGY

After obtaining approval from the Institutional Ethics Committee, eligible ischemic stroke patients admitted to the Departments of General Medicine and Neurology were enrolled in the study. A detailed clinical history and physical examination were performed.

Patients underwent:

- Neuroimaging (MRI/CT Brain)
- Carotid Doppler imaging
- Electrocardiography
- Transthoracic 2D echocardiography

Based on clinical evaluation and investigations, patients were categorized into:

- Cardioembolic stroke
- Non-cardioembolic stroke
- Embolic Stroke of Undetermined Source (ESUS)

The diagnosis of ESUS was established in patients with:

- Non-lacunar ischemic stroke
- Absence of significant extracranial or intracranial stenosis (≥50%)
- No major cardioembolic source
- No other specific identifiable cause of stroke

Left atrial volume was measured using 2D echocardiography and indexed to body surface area to calculate LAVI.

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Independent t-test were used for comparison of means. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 96 patients with ischemic stroke were included in the study. The mean age of the study population was 61.15 ± 14.98 years, with patients aged more than 60 years constituting 57.3% of the study population. Male predominance was observed, accounting for 64.6% of the cases. The mean Left Atrial Volume Index (LAVI) among all patients was 16.46 ± 5.38 mL/m². Embolic Stroke of Undetermined Source (ESUS) was the most common stroke subtype (45.8%), followed by non-cardioembolic stroke (37.5%) and cardioembolic stroke (16.7%). ESUS patients demonstrated the highest mean LAVI values (17.46 ± 5.36 mL/m²), whereas non-cardioembolic stroke patients had lower LAVI values. Although the difference was not statistically significant (p=0.129), the trend suggests relatively greater atrial remodeling among ESUS patients.

Table 1: Demographic Characteristics and LAVI Distribution Among Stroke Subtypes

Variable	**Number (%) / Mean ± SD**
Total patients	96
Age (years)	61.15 ± 14.98
Age <60 years	41 (42.7%)
Age >60 years	55 (57.3%)
Gender	
Male	62 (64.6%)
Female	34 (35.4%)
Left Atrial Volume (mL)	28.22 ± 8.91
LAVI (mL/m²)	16.46 ± 5.38
Minimum LAVI	6.25
Maximum LAVI	33.18
Stroke Subtypes	
Cardioembolic	16 (16.7%)
Non-cardioembolic	36 (37.5%)
ESUS	44 (45.8%)
Mean LAVI Across Stroke Subtypes (mL/m²)	

Variable	Number (%) / Mean ± SD
Cardioembolic	16.90 ± 6.46
Non-cardioembolic	15.05 ± 4.70
ESUS	17.46 ± 5.36
p-value	0.129

DISCUSSION

The present study evaluated the association between Left Atrial Volume Index (LAVI) and ischemic stroke subtypes, with particular emphasis on Embolic Stroke of Undetermined Source (ESUS). The mean age of the study population was 61.15 years, with a male predominance (64.6%), which is comparable to previous stroke studies demonstrating higher incidence among elderly males. Hypertension and diabetes mellitus were the most common comorbidities, consistent with established vascular risk factors for ischemic stroke.

A key finding of the study was that ESUS patients demonstrated the highest mean LAVI values (17.46 ± 5.36 mL/m²), whereas non-cardioembolic stroke patients had comparatively lower values. Although the association did not reach statistical significance (p=0.129), the observed trend supports the hypothesis that atrial remodeling and atrial cardiopathy may contribute to the pathogenesis of ESUS. Similar findings have been reported by Jordan K et al. and Kamel H et al., who demonstrated increased left atrial size and structural abnormalities among ESUS patients.

In the present study, atrial fibrillation was identified in only 5.2% of patients; however, elevated LAVI values were observed among ESUS cases. This suggests that structural and functional atrial abnormalities may predispose to thromboembolism even in the absence of overt atrial fibrillation. These findings support the emerging concept of atrial cardiopathy as an independent mechanism for embolic stroke.

LAVI assessment is simple, non-invasive, reproducible, and readily available through transthoracic echocardiography. Incorporating LAVI into routine stroke evaluation may help identify patients requiring prolonged rhythm monitoring and further cardiac evaluation for occult cardioembolic sources.

LIMITATIONS

1. The study was conducted at a single tertiary care center.
2. The sample size was relatively small.
3. Extended rhythm monitoring for occult atrial fibrillation was not performed in all patients.
4. Long-term follow-up for recurrent stroke was not available.
5. Advanced atrial functional parameters such as left atrial strain were not assessed.

CONCLUSION

The present study demonstrated that patients with Embolic Stroke of Undetermined Source (ESUS) had relatively higher Left Atrial Volume Index (LAVI) values compared to non-cardioembolic stroke patients, suggesting a possible association between atrial remodeling and ESUS. Although the difference was not statistically significant, the findings support the emerging role of atrial cardiopathy in the pathogenesis of embolic stroke. Elevated LAVI in the absence of overt atrial fibrillation indicates that subclinical atrial dysfunction may contribute to occult cardioembolic mechanisms. As LAVI assessment is simple, non-invasive, and widely available, it may serve as a useful echocardiographic marker for risk stratification and identification of patients requiring further cardiac evaluation and prolonged rhythm monitoring. Further multicentric studies with larger sample sizes are needed to establish its prognostic significance in ESUS.

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