Print ISSN 1110-208X

Online ISSN 2357-0016

Echocardiographic Assessment of Left Atrial Function for Prediction of Efficacy of Catheter Ablation for Atrial Fibrillation

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Received:

Accepted:

Abstract

Background: Atrial fibrillation (AF) is among the most frequently encountered cardiac arrhythmias, exerting a significant burden on both primary and secondary healthcare services. **This aimed to** evaluate the utility of detailed Left Atrial (LA) functional assessment via Speckle tracking echocardiography (STE) in cases with non-valvular AF without structural heart disease, especially in those without enlarged LA, in predicting the outcome after catheter ablation (CA) for atrial fibrillation. **Methods:** This prospective cohort investigation enrolled 36 cases with non-valvular AF eligible for CA. All participants underwent transthoracic echocardiography, including conventional imaging, Doppler assessment, and STE, followed by CA. **Results**: LA speckle tracking analysis proved valuable in identifying appropriate candidates for CA among cases with AF and normal findings on conventional echocardiography. Age, LVEF, LAVI, GLASr, and GLASct emerged as independent predictors of successful CA, while LAD, LAstf, GLAScd, GLASRr, and GLASRct did not. LAVI and GLASr significantly predicted CA success at thresholds >30 ml/m² and >25.2, respectively ($P < 0.001$), with sensitivity of 88.24% and 100%, specificity of 94.74% for both, PPV of 93.7% and 94.4%, NPV of 90% and 100%, and AUCs of 0.981 and 0.969, respectively. **Conclusion:** LA speckle tracking analysis is a valuable tool for selecting candidates for CA in AF cases without structural heart disease and with unremarkable conventional echocardiographic findings. Age, LVEF, LAVI, GLASr, and GLASct serve as independent predictors of CA efficacy, whereas LAD, LAstf, GLAScd, GLASRr, and GLASRct do not. This is especially relevant in cases without LA enlargement, no structural cardiac abnormalities, and undergoing first-time CA.

Keywords: Echocardiographic; Left Atrial Function; Catheter Ablation; Atrial Fibrillation.

Introduction

Atrial fibrillation (AF) is widely acknowledged as a highly prevalent and clinically significant cardiac arrhythmia encountered in contemporary medical practice. It exerts a profound and multifaceted impact on various levels of the healthcare system, influencing not only individual patient outcomes but also broader organizational and economic aspects of healthcare delivery. AF affects both primary and secondary care services, thereby contributing to a considerable burden on global healthcare infrastructures. AF leads to greater health burdens, diminished life satisfaction, and an elevated chance of serious issues like stroke and heart failure, requiring ongoing treatment and continuous monitoring. The overall burden of AF is projected to rise substantially in the coming decades, with estimates suggesting a potential doubling in its prevalence. This increase is largely driven by a convergence of factors including demographic shifts toward an aging population, escalating rates of chronic comorbidities, greater awareness among healthcare providers and cases, and continuous progress in diagnostic and monitoring technologies that facilitate earlier and more accurate detection [(1)].

Catheter ablation (CA) serves as a fundamental therapeutic intervention in the treatment of AF. Despite its widespread application, recurrence of AF post-ablation remains one of the most frequently encountered and clinically relevant adverse events, affecting an estimated 30% to 50% of cases [(2)].

Although CA has been routinely performed for over two decades, outcomes remain suboptimal. This limitation underscores a critical clinical challenge: the accurate identification of cases who are most likely to achieve favorable outcomes following ablation [(3)].

A variety of elements have been proposed as potential indicators of CA success, ranging from conventional cardiovascular risk factors to left ventricular (LV) impairment, enlargement of the left atrium (LA), and elevated levels of cardiac fibrosis. [(4)].

This clinical gap has generated increasing interest in the use of more advanced and nuanced imaging approaches for evaluating LA function. LA fulfills a versatile role in cardiac performance, sequentially acting as a holding chamber during ventricular contraction, a passive passageway in early ventricular relaxation, and an active pump in the final phase of diastole. This layered functionality demands a thorough and integrative evaluation strategy. Speckle tracking echocardiography (STE) has gained recognition as a cutting-edge, non-invasive apprach for analyzing myocardial motion. By examining atrial strain throughout the different functional phases, reservoir, conduit, and contraction, STE enables refined assessment of atrial dynamics and may improve therapeutic outcomes prediction [5].

Among these metrics, LA strain has shown promising utility in prognostication following CA. It provides insights into the intrinsic compliance and functional integrity of the atrial myocardium, which may not be apparent through conventional echocardiographic methods [6]. Nevertheless, the predictive value of LA strain remains subject to several limitations. Many existing investigations are constrained by relatively small sample sizes, heterogeneous patient populations, and variability in imaging protocols and interpretation approaches. These methodological inconsistencies limit the generalizability of findings and emphasize the necessity for large-scale, well-controlled, and standardized research initiatives. A major contribution to this field was made by Badano and colleagues in 2018, who introduced a standardized framework for assessing LA deformation via STE, thereby providing a foundation for future investigations and potential clinical application [7]

The investigation assessed whether LA function measured by STE can predict CA outcomes in non-valvular AF cases without structural heart disease, specifically those with normal LA size.

Patients and methods

Patients:

This prospective cohort research was meticulously designed to include a total of 36 cases who had been diagnosed with non-valvular AF, each of whom was deemed clinically eligible for CA. The investigation was conducted at the National Heart Institute. The recruitment and data collection phases were carried out over a six-month period, spanning from June 2023 to December 2023, ensuring an adequate time frame for thorough patient evaluation and follow-up.

Prior to enrollment, every participant was thoroughly briefed on the investigation's goals, methodology, possible risks, and anticipated benefits. Each individual provided written consent. The research protocol was officially reviewed and approved by the Ethics Committee of the Faculty of Medicine, Benha University. This approval process ensured that all components of the investigation complied with institutional and international ethical standards, including the Declaration of Helsinki and relevant national guidelines.

The eligibility criteria for inclusion in the investigation were deliberately stringent to ensure the homogeneity and appropriateness of the investigation population.

Participants were required to have a confirmed diagnosis of non-valvular AF, no evidence of structural heart disease based on clinical and echocardiographic assessments, and to be undergoing CA for the first time. These inclusion parameters were selected to minimize potential confounding variables and to focus the investigation on a specific and clinically relevant subgroup of AF cases.

In contrast, **exclusion criteria** were rigorously applied to eliminate individuals whose clinical characteristics could interfere with the accuracy of the investigation findings. Cases were excluded if they had any form of valvular heart disease, as defined by the diagnostic criteria outlined in the guidelines of the European Society of Cardiology. Additionally, individuals with a left ventricular ejection fraction (LVEF) of less as opposed to 40% were excluded, given the potential impact of LV systolic dysfunction on atrial remodeling and procedural outcomes. Further exclusion criteria included poor-quality two-dimensional transthoracic echocardiographic (2D-TTE) images that hindered the accurate visualization and analysis of the left atrial (LA) wall, as well as any patient who declined to give his consent or express unwillingness to contribute in the investigation.

Methods:

To ensure a comprehensive evaluation of each participant's clinical status and suitability for inclusion, a standardized pre-enrollment assessment protocol was implemented. Each patient underwent detailed history-taking, with particular attention to any prior episodes of paroxysmal AF, given their potential impact on outcomes following CA. A full clinical examination was performed, including HR and BP measurements, as well as focused assessment of the cardiovascular and respiratory systems to identify signs of HF or other relevant pathology. Diagnostic evaluation incorporated multiple non-invasive imaging modalities, including TTE for assessing cardiac morphology and chamber dimensions, Doppler studies to analyze intracardiac flow dynamics, and STE for detailed quantification of LA strain across functional phases.

Conventional Echocardiography:

TTE was conducted utilizing the high-end Vivid E95 system (GE Medical System), known for its advanced imaging technology, which delivers superior image resolution and dependable diagnostic performance. Comprehensive echocardiographic assessments were carried out to evaluate cardiac structure and function, with particular focus on LV measurements and overall chamber geometry. All measurements, including key LV parameters, were obtained in strict accordance with the most current and widely endorsed clinical guidelines to ensure methodological consistency. LA diameter was specifically measured at end-systole from the parasternal long-axis view, offering a reliable anatomical window. To determine maximum LAV, the biplane area-length method was employed via both apical 4C and 2C views, allowing for precise volumetric estimation through orthogonal planes. The resulting LAV was then indexed to the patient's BSA to calculate LAVI, enabling standardized comparison across individuals with different body sizes and compositions. [8]

Doppler:

Beyond the standard TTE assessment, additional hemodynamic evaluation was conducted via Doppler-based approaches. PW Doppler was employed to measure mitral inflow velocities, specifically the early (E) and late (A) diastolic waves, recorded at the level of the mitral valve leaflet tips in the apical 4C view. These measurements were used to assess the pattern and timing of LV filling. Furthermore, TDI was applied at the septal and lateral aspects of the mitral annulus to assess myocardial relaxation velocities during early (e') and late (a') diastole. These annular velocities provided insight into regional myocardial mechanics and were essential for distinguishing between normal and abnormal relaxation patterns. The E/e' ratio was subsequently estimated by dividing the transmitral E velocity by the mean of septal and lateral e' values [8].

Speckle tracking:

STE was employed as an advanced echocardiographic modality to quantify peak longitudinal LA strain (LAS) and strain rate (LASR) across the three functional phases of LA mechanics: reservoir (r), conduit (cd), and contraction (ct). This technique enabled a refined, non-invasive evaluation of intrinsic LA myocardial function beyond conventional size and volume measurements. All LAS parameters were assessed in accordance with the most recent expert consensus guidelines jointly published by the European Association of Cardiovascular Imaging, the American Society of Echocardiography, and the Industry Task Force on the standardization of myocardial deformation imaging [7].

Image acquisition was conducted from the apical 4C and 2C views, ensuring optimal visualization of the LA walls, with frame rates maintained between 60 and 80 frames per second to guarantee sufficient temporal resolution for accurate speckle tracking. A stable cine loop encompassing three consecutive cardiac cycles was recorded, stored in digital format, and subsequently analyzed offline via EchoPac software (GE Healthcare). Manual tracing of the LA endocardial border was performed in both views to define the region of interest (ROI), which was automatically divided into six anatomical segments per view. Following the initial tracking analysis, each segment underwent a quality assessment to confirm adequate tracking fidelity. Where necessary, manual corrections were applied to optimize the ROI. The software then generated strain and strain rate curves for each segment throughout the cardiac cycle. Global LAS values for each phase (LASr, LAScd, and LASct) were computed by averaging the peak strain measurements across all LA segments. To standardize temporal alignment, the zero-strain reference point was set at LV end-diastole, consistent with consensus recommendations. Additionally, derived indices such as LA stiffness index (LAstf) and the E/e' to LASr ratio were calculated to further elucidate LA mechanical behavior and its interplay with LV diastolic function. These parameters offer valuable insights into LA compliance and pressure-loading conditions, supporting their growing role in risk stratification and outcome prediction following CA [9].

Catheter ablation: The CA approach was performed via either radiofrequency CA (RFCA) or cryo-balloon (CB) ablation approaches, both of which are recognized as standard, evidence-based modalities in the management of AF. The choice of technique was based on operator preference, patient-specific anatomical and clinical considerations, and institutional protocols. Each approach was conducted in accordance with internationally accepted guidelines and consensus statements, ensuring adherence to best practices in terms of safety, efficacy, and procedural consistency. Both RFCA and CB ablation aim to achieve pulmonary vein isolation (PVI), which is the cornerstone of rhythm control in cases with paroxysmal or persistent AF[3].

Cases enrolled in the investigation were randomly allocated to undergo either RFCA or CB ablation, ensuring balanced distribution and minimizing allocation bias. In the RF group, PVI was performed via a point-by-point technique following a double trans-septal puncture. Irrigated-tip ablation catheters (Thermocool SF or Thermocool Smart Touch ST; Biosense Webster, USA) were utilized to deliver RF energy with precision. Electroanatomical mapping and catheter navigation were guided via the CARTO 3 system (Biosense Webster, USA), in conjunction with a circular mapping catheter (LASSO; Biosense Webster, USA) positioned at the PV ostia to confirm entry and exit block, ensuring successful electrical isolation.

In the CB group, PVI was achieved via a single trans-septal puncture approach. A steerable 15 Fr sheath (FlexCath Advance; Medtronic, Minnesota, USA) was introduced into the LA to facilitate catheter stability and maneuverability. A dedicated inner lumen mapping catheter (Achieve; Medtronic, Minnesota, USA) was advanced into each PV ostium to enable real-time recording of PV potentials and verification of acute isolation. Subsequently, a 28 mm cryoballoon (Arctic Front or Arctic Front Advance; Medtronic, Minnesota, USA) was deployed and positioned at each PV ostium to deliver cryothermal energy, achieving circumferential PVI through cryogenic tissue ablation. All approachs were performed by experienced electrophysiologists following standardized protocols to ensure procedural consistency and reproducibility across both ablation strategies.

Follow-up:

The follow-up period for the cases in this investigation lasted a full year. The cases were seen for follow-up visits at the outpatient clinic at 3, 6, and 12 months after undergoing CA. Additionally, to monitor their progress and assess any potential recurrence of AF, 24-hour Holter ECG monitoring was performed at the 6-month follow-up visit via the DMS 300-4A system (DM Software, Nevada, USA). These follow-up visits and continuous monitoring were integral to assessing the long-term success of the ablation approach and ensuring the cases' overall well-being.

Approval code: MD 8-4-2023

Statistical analysis

All statistical approachs were executed via SPSS v26 (IBM Corp., Chicago, IL, USA). Quantitative data were first examined for normality. Variables demonstrating a normal distribution were expressed as means with their corresponding standard deviations (mean ± SD), and comparisons between independent groups were performed via the student's t-test. For data not following a normal distribution, results were presented as medians along with interquartile ranges (IQR), and differences were assessed via the non-parametric Mann-Whitney U test. Categorical variables were displayed as counts and percentages to summarize distribution across groups. The discriminative ability of selected measures was analyzed through ROC curves, enabling assessment of diagnostic accuracy. A significance threshold was set at a Pbelow 0.05 for all statistical tests, applying a two-tailed approach.

Results

(Table 1) displays demographic data, comorbidities, duration of AF, vital signs, CHADS-VASC and medication used of the studied cases.

(Table 2) shows echocardiographic characteristics and CA success of the studied cases.

Age was significantly diminished in cases with successful CA as opposed to cases with failed CA ($P<0.001$). Sex, BMI, and duration of AF were insignificantly different between the two groups. Cases with successful CA had significantly diminished SBP and DBP as opposed to cases with failed CA ($P<0.001$) while heart rate and CHADS-VASC were insignificantly different between the two groups. Beta blocker and anti-arrhythmic use were comparable and ACE inhibitors was significantly diminished with cases with successful CA as opposed to cases with failure CA ($P<0.001$). (**Table 3)**

LVEF and GLASRr were significantly raised in cases with successful CA as opposed to cases with failed CA

(P<0.001) while LAD, LAV index, GLASr, LAstf, GLAScd, GLASct and GLASRct were significantly diminished in cases with successful CA as opposed to cases with failed CA (*P*<0.001). (**Table 4)**

In Univariate regression, age, LVEF, LAV index, GLASr and GLASct were independent predictors for efficacy of CA for AF while LAD, LAstf, GLAScd, GLASRr and GLASRct were not. In multivariate regression, LAV index and GLASr were independent predictors for efficacy of CA for AF while age, LVEF and GLASct were not. (**Table 5)**

LAVI and GLASr can significantly predict efficacy of CA for AF at cut off >30 ml/m2 and >25.2 respectively and Pof <0.001) with Sensitivity 88.24% and 100%respectively, Specificity 94.74% for both, PPV 93.7% and 94.4% respectively, NPV 90% and 100% respectively and AUC 0.981and 0.969 respectively. (**Figure 1)**

Table 1: Demographic data, Comorbidities, Duration of atrial fibrillation, Vital signs, CHADS-VASC and Medication used of the studied cases

		n = 36
Age (years)		58.2 ± 5.6
Sex	**Male**	20 (55.56%)
	Female	16 (44.44%)
BMI (kg/m^2)		31.7 ± 2.34
Comorbidities		
DM		7 (19.44%)
CAD		7 (19.44%)
HTN		18 (50%)
Hyperlipidemia		17 (47.22%)
Duration of atrial fibrillation		
DAF (years)		4.3 ± 1.59
Vital signs		
SBP (mmHg)		126.9 ± 8.01
DBP(mmHg)		78.7 ± 5.35
Heart rate (bpm)		62.8 ± 5.74
CHADS-VASC		2.0(0-3)
Medication used		
BB		18 (50%)
Antiarrhythmic		8 (22.22%)
ACEI		18 (50%)

Data are presented as Mean ± SD or frequency (%), BMI: body mass index, DM: diabetes, CAD: coronary artery disease, HTN: hypertension BB: beta blocker use, ACEI: angiotensin converting enzyme inhibitors use.

Table 2: Echocardiographic characteristics, Catheter ablation success of the enrolled cases

	n=36
LVEF (%)	64.2 ± 2.29
LAD (cm)	36.2 ± 1.66
LAV index (ml/m^2)	29.8 ± 2.75
GLASr (%)	26.6 ± 5.93
LAstf	0.3 ± 0.14
GLAScd (%)	-17 ± 3.69
GLASct (%)	-13.9 ± 6.07
GLASRr (S^{-1})	1.1 ± 0.17
GLASRct (S^{-1})	-1.4 ± 0.17
Catheter ablation success	19 (52.78%)

Data are presented as Mean ± SD or frequency (%), LVEF: left ventricular ejection fraction, LAD: left atrial diameter, LAV: left atrial volume, GLASr= global left atrial strain rate, LAstf = left atrial stiffness index, LAScd = left atrial conduit strain, LASct = left atrial contractile strain, LASr = left atrial reservoir strain, LASRct = left atrial contractile strain rate, LASRr = left atrial reservoir strain rate

Table 3: Demographic data, Duration of atrial fibrillation, Comorbidities, Vital signs, CHADS-VASCand Medication used of the two groups

		CA success(n=19)	CA failure (n=17)	P value
Age (years)		54.74 ± 4.45	62 ± 4.09	<0.001*
Sex	**Male**	8 (42.11%)	12 (70.59%)	0.086
	Female	11 (57.89%)	5 (29.41%)	
BMI (kg/m^2)		31.58 ± 2.29	31.88 ± 2.45	0.703
Duration of atrial fibrillation		4.79 ± 1.27	3.82 ± 1.78	0.067
Comorbidities				
DM		0 (0%)	7 (41.18%)	0.002*
CAD		0 (0%)	7 (41.18%)	0.002*
HTN		1 (5.26%)	17 (100%)	<0.001*
Hyperlipidemia		1 (5.26%)	16 (94.12%)	<0.001*
Vital signs				
SBP (mmHg)		120.47 ± 4.54	134.06 ± 3.72	<0.001*
DBP(mmHg)		75.53 ± 3.92	82.29 ± 4.43	<0.001*
Heart rate (bpm)		62.47 ± 5.54	63.18 ± 6.11	0.720
CHADS-VASC		1 (0-1)	2(1-3)	0.290
Medication used				
BB		10 (52.63%)	8 (47.06%)	0.738
AA		4 (21.05%)	4 (23.53%)	0.858
ACEI		1 (5.26%)	17 (100%)	<0.001*

Data are presented as Mean ± SD, frequency (%) or Median (IQR), BMI: body mass index. CA: Catheter ablation, DM: diabetes, CAD: coronary artery disease, HTN: hypertension,SBP: systolic blood pressure, DBP: diastolic blood pressure, BB: beta blocker use, AA: anti-arrhythmic use, ACEI: angiotensin converting enzyme inhibitors use,*: statistically significant as P<0.05

Table 4: Echocardiographic characteristics of the two groups

	CA success (n=19)	CA failure(n=17)	P value
LVEF (%)	65.68 ± 1.57	62.47 ± 1.7	<0.001*
LAD (cm)	34.79 ± 0.79	37.71 ± 0.77	<0.001*
LAV index (ml/m^2)	27.63 ± 1.54	32.18 ± 1.51	<0.001*
GLASr (%)	21.96 ± 3.3	31.79 ± 3.26	<0.001*
LAstf	0.24 ± 0.05	0.47 ± 0.09	<0.001*
GLAScd (%)	-19.97 ± 1.81	-13.59 ± 1.82	<0.001*
GLASct (%)	-15.95 ± 7.7	-11.57 ± 1.76	0.028*
GLASRr (S^{-1})	1.29 ± 0.03	0.99 ± 0.12	<0.001*
GLASRct (S^{-1})	-1.49 ± 0.04	-1.2 ± 0.12	<0.001*

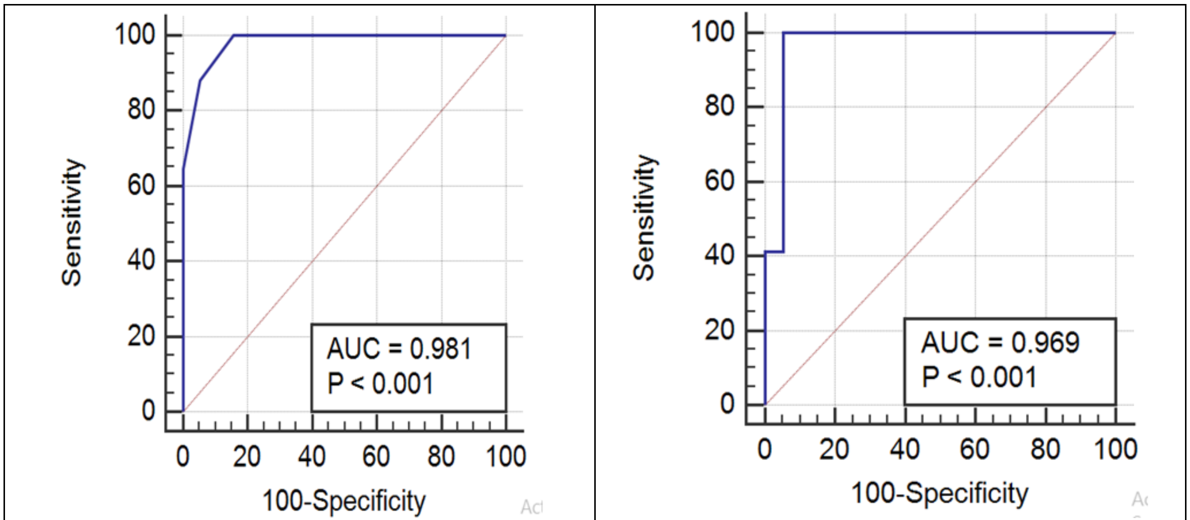
Data are presented as Mean ± SD, frequency (%) or Median (IQR , LVEF: left ventricular ejection fraction, LAD: left atrial diameter, LAV: left atrial volume, GLASr= global left atrial strain rate, LAstf = left atrial stiffness index, LAScd = left atrial conduit strain, LASct = left atrial contractile strain, LASr = left atrial reservoir strain, LASRct = left atrial contractile strain rate, LASRr = left atrial reservoir strain rate

*: statistically significant as P<0.05

Table 5: Univariate and multivariate regression for prediction of efficacy of catheter ablation for atrial fibrillation

Variable	Univariate regression		Multivariate regression	
	OR(95% CI)	**P value**	**OR(95% CI)**	**P value**
Age (years)	1.71 (1.19 - 2.45)	**0.003***	0.1528(-)	0.358
LVEF (%)	0.37(0.214 - 0.668)	**<0.001***	0.9228 (-)	0.361
LAD (cm)	1.52E+009	0.997	--	--
LAVI (ml/m^2)	9.445(1.33 - 66.971)	**0.024***	25.1E+006(-)	**0.002***
GLASr (%)	1.999(1.269 - 3.149)	**0.002***	102.0929 (-)	**<0.001***
LAstf	--	0.997	--	--
GLAScd (%)	1.92E+012	0.997	--	--
GLASct (%)	1.281(1.026 - 1.601)	**0.028***	8.2749 (-)	0.153
GLASRr (S^{-1})	1.19E-240	0.997	--	--
GLASRct (S^{-1})	--	0.997	--	--

LVEF: left ventricular ejection fraction, LAD: left atrial diameter, LAV: left atrial volume, GLASr= global left atrial strain rate, LAstf = left atrial stiffness index, LAScd = left atrial conduit strain, LASct = left atrial contractile strain, LASr = left atrial reservoir strain, LASRct = left atrial contractile strain rate, LASRr = left atrial reservoir strain rate)



(A)	(B)

Figure 1: ROC curve of (A) LAVI and (B) GLASr for prediction of efficacy of catheter ablation for atrial fibrillation

Discussion

Our findings indicated that cases who experienced successful CA had significantly diminished ages as opposed to those with failed CA. These observations are consistent with those reported in a meta-analysis by Boehmer and co-authors which investigated the impact of age on outcomes following initial cryoballoon ablation in a cohort of 953 patients with either paroxysmal or persistent AF. With a median follow-up duration of 18 months, the investigation employed multivariable regression analysis to explore predictors of AF recurrence. The age emerged as the sole variable independently linked to post-ablation recurrence. The authors concluded that older patients experienced a significantly elevated rate of AF recurrence after CA as opposed to their younger counterparts, underscoring the influence of age on long-term procedural success. [(10)].

Regarding sex-related differences, our findings revealed comparable outcomes between the two groups, aligning with observations from a investigation by Ritu Yadav and co-authors, which analyzed outcomes in 1,346 patients undergoing their first CA for AF. The cohort comprised 896 males (66.5%). In that investigation, females were generally older at the time of CA, with a mean age of 66.2 years as opposed to 62.4 years in males. They also exhibited elevated CHA_2DS_2-VASc scores (3 vs. 2; $p < 0.001$), indicating a greater baseline stroke risk. Persistent AF was more prevalent among male patients (35.3%) as opposed to females (25.3%), a difference that was also statistically significant ($p<0.001$) [11].

With regard to BMI, our findings demonstrated comparable values between the groups, consistent with the observations reported by Tabaja and co-authors. Their investigation concluded that AF ablation is generally safe and associated with a low complication rate across all BMI categories. However, they also found that morbid obesity (BMI ≥ 40) was significantly associated with reduced CA success [12].

In our investigation, the duration of AF was found to be comparable between the two groups, showing no statistically significant difference. This aligns with the conclusions of a meta-analysis conducted by Chew and co-authors, who reported that a shorter interval between initial AF diagnosis and CA is associated with a elevated likelihood of procedural success[13].

Additionally, our findings revealed that patients who experienced successful CA had significantly diminished rates of CAD compared to those in the failed CA group ($P < 0.05$). This outcome contrasts with the investigation by Fuqian Guo and co-authors, who observed that while CAD in the presence of AF may be associated with poorer overall clinical outcomes, it did not significantly influence the risk of AF recurrence following CA. The divergence in findings may stem from variations in investigation design, population characteristics, and selection criteria across the two investigations [14].

Cases with successful CA showed significantly diminished rates of DM compared to those with failed CA. This aligns with findings by Mingjie Lin and co-authors, who reported a elevated incidence of AF recurrence (24.6% vs. 34.4%) and increased frequency of MACCE (6.5% vs. 9.3%) in cases with DM. Kaplan-Meier curves demonstrated that DM significantly raised the risk of AF recurrence (HR: 1.506, 95% CI: 1.165–1.948, $p = 0.0003$). This association held true even in the propensity-matched cohort. Cox regression further confirmed DM as an independent predictor of AF recurrence after adjusting for other risk factors. new-onset DM also emerged as an independent predictor. Additionally, DM was identified as a standalone risk factor for MACCE (HR: 2.273, 95% CI: 1.120–4.615, $p = 0.023$). Based on these findings, the authors concluded that both established and newly diagnosed DM independently contribute to AF recurrence following CA [15].

Our findings also showed that cases with successful CA had significantly diminished rates of hypertension as opposed to those with failed CA. This aligns with the research of Tao Wang and co-authors., who concluded that hypertension significantly affects the LA electro-mechanical characteristics in AF cases, with the LA substrate influencing the outcome of CA [16].

Regarding CHADS-VASC scores, our investigation found no significant difference between the two groups, a result that contrasts with the findings of Jacobs and co-authors., who concluded that increasing CHADS2 and CHA2DS2-VASc scores were associated with raised recurrence rates of AF and atrial flutter. This discrepancy may be due to the smaller sample size in our investigation and the limited number of cases with raised CHADS-VASc scores [(17)].

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Additionally, our findings revealed that LVEF was significantly raised in cases with successful CA as opposed to those with failed CA. However, these results do not support the findings of the meta-analysis by Jin Jin and co-authors., who concluded that there was no direct correlation between LVEF values and AF recurrence after CA, particularly when baseline LVEF values are normal or only mildly decreased [(19)].

Our findings revealed that both LAD and LAVi were significantly diminished in cases with successful CA as opposed to those with failed CA. These results are consistent with the findings of Augustine Njoku and co-authors., who reported that cases with AF recurrence following RFA had a raised mean LAV/LAVi as opposed to those without recurrence [(20)].

LAstf was significantly diminished in cases who experienced successful CA as opposed to those with failed CA. These results were consistent with findings from Eduardo Thadeu de Oliveira Correia and co-authors., who concluded that non-invasive assessments of LA stiffness prior to CA could serve as a potential screening factor. Such evaluations could help identify cases at raised risk for AF recurrence and the development of stiff LA syndrome [(21)].

Our findings also revealed that GLASr was significantly diminished in cases with successful CA as opposed to those with failed CA. These results were supported by Xin-Xin Ma and co-authors., who highlighted that diminished baseline LA deformation, as reflected by diminished GLASr values obtained through 2D STE, was a strong predictor of AF recurrence following CA in both paroxysmal and persistent forms of the condition [(22)].

Additionally, we observed that GLASRr was significantly raised in cases with successful CA, while GLASRct was significantly diminished in cases with successful CA as opposed to those with failed CA (P<0.001). These findings align with those of Suman Kuppahally and co-authors., who concluded that LA wall fibrosis, as identified through delayed-enhancement MRI, has been shown to correlate negatively with both LA strain and strain rate, which reflect atrial function and are closely linked to overall AF burden. The investigators highlighted that echocardiographic assessment offers a practical and efficient means of evaluating both structural and functional remodeling of the LA [23].

There are several limitations to this investigation. Most the cohort size was relatively small, and the follow-up period was somewhat short. Although 24-hour Holter ECG monitoring was conducted at the 6-month mark post-CA and patients were routinely assessed during outpatient visits throughout the 12-month follow-up, the use of both RFCA and CBA introduced procedural heterogeneity. This variation in CA technique could have influenced the consistency and interpretation of the outcomes, highlighting the need for larger-scale, technique-specific investigations with extended follow-up durations.

Conclusion

The use of LA speckle tracking analysis seems to play a significant role in choosing cases for CA in those with AF, particularly when standard echocardiographic parameters do not show abnormalities. Our investigation found that age, LVEF, LAVI, GLASr, and GLASct were independent predictors of CA efficacy for AF, while LAD, LAstf, GLAScd, GLASRr, and GLASRct were not. In cases without an enlarged LA, no structural heart disease, and undergoing first-time CA, we highly recommend assessing LA function via transthoracic echocardiography and speckle tracking, with particular attention to LAVI and GLASr. These parameters can help predict the effectiveness of CA for AF and provide insights into the likelihood of recurrence.

Sources of funding

This work was carried out independently and did not receive financial backing from governmental bodies, commercial entities, or charitable organizations.

Conflict of Interest Disclosure

The authors affirm that there are no financial or personal relationships that could be perceived as potential conflicts of interest concerning this research.

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To cite this article: Safaa S. Imam, Essam A. Elabbady, Khalid E. Elrabaat, Shereen I. Farag. Echocardiographic Assessment of Left Atrial Function for Prediction of Efficacy of Catheter Ablation for Atrial Fibrillation. BMFJ XXX, DOI: 10.21608/bmfj.2025.405008.2552