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ORIGINAL ARTICLE

Circulating Galectin-3 is Associated With Left Atrial Appendage Remodelling and Thrombus Formation in Patients With Atrial Fibrillation

Zhengde Tang, MD, Lefeng Zeng, MD, Yanjun Lin, MD, Zhihua Han, MD, PhD, Jun Gu, MD, PhD, Changqian Wang, MD, PhD **, Huili Zhang, MD, PhD *

Department of Cardiology, Shanghai Ninth People's Hospital, Shanghai Jiaotong University School of Medicine, Shanghai, China

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Background Left atrial appendage (LAA) is gaining increasing attention in patients with atrial fibrillation (AF) in the context of cardioembolic stroke. Galectin-3 (Gal-3) is a mediator of profibrotic pathways and is associated with an increased incidence of heart failure. However, the role of Gal-3 in LAA remodelling and thrombus formation in AF has not been evaluated.

Methods This prospective study included 153 consecutive patients with paroxysmal (n = 58), persistent (n = 55) or permanent (n = 40) nonvalvular AF. The serum level of Gal-3 was measured by enzyme-linked immunosorbent assay. The morphology and function of LAA were determined by transoesophageal echocardiography.

Results Left atrial appendage thrombus was observed in 22 patients (2 in paroxysmal AF, 11 in persistent AF and 9 in permanent AF). Significant differences among patients with different types of AF were found in terms of LAA morphology (orifice diameter and depth) and function (flow velocity and tissue Doppler contracting velocity) as well as serum levels of Gal-3. Furthermore, patients with persistent or permanent AF had higher levels of Gal-3. High Gal-3 level was closely related to LAA flow velocity and occurrence of LAA thrombus. Multivariate logistic regression analysis revealed that Gal-3 was an independent determinant of LAA thrombus in patients with AF. Receiver operating characteristic (ROC) curves related to LAA thrombus formation established a cut-off point for Gal-3 >18.95 ng/ml.

Conclusions Cardiac rhythm disturbances caused by AF may lead to morphologic and functional remodelling of LAA. The serum level of Gal-3 was significantly correlated with LAA remodelling in patients with AF. High levels of Gal-3 were also a predicator for LAA thrombus formation.

Keywords Left atrial appendage • Atrial fibrillation • Transoesophageal echocardiography • Galectin-3

*Corresponding author at: Department of Cardiology, Shanghai Ninth People's Hospital, Shanghai JiaoTong University School of Medicine, 639 Zhizaoju Road, Shanghai 200011, China. Tel: 86-21-23271699-5556, Fax: 86-21-63087768., Email: huilizhang815@163.com

**Corresponding author at: Department of Cardiology, Shanghai Ninth People's Hospital, Shanghai JiaoTong University School of Medicine, 639 Zhizaoju Road, Shanghai 200011, China. Tel: 86-21-23271699-5777, Fax: 86-21-63087768., Email: changqianwang@hotmail.com

Introduction

Atrial fibrillation (AF) is a common type of arrhythmia encountered in clinical practice. AF carries a five-fold increase in the incidence of cardioembolic stroke and a three-fold risk of mortality [1]. Compelling evidence has revealed that the left atrial appendage (LAA) is implicated as a primary site of cardiac thrombus in patients with AF. Furthermore, previous studies have elucidated that structural and functional LAA remodelling occurs during the development and progression of AF from paroxysmal to persistent or permanent types [2,3]. In addition to LAA remodelling, atrial interstitial fibrosis is another important consequence of AF and underlies the potential for AF perpetuation and thrombus formation [4].

Galectin-3 (Gal-3) is a beta-galactoside binding lectin that is produced by activated macrophages and plays an active role in profibrotic pathways. It contributes to the development of heart failure and may be a potential biomarker of cardiac fibrosis and adverse cardiac remodelling [5]. Since cardiac fibrosis and heart failure are well-established consequences of AF [1], the role of Gal-3 in risk assessment of AF and related complications is an appealing perspective. Recently, several studies revealed that Gal-3 is likely to be an indicator of atrial interstitial remodelling involved in AF [6,7]. Gal-3 levels significantly increased in patients with permanent AF and have been closely related to atrial appendage fibrosis assessed with Masson's trichrome staining [7]. These findings lead the way to further studies for investigating the role of this biomarker in the setting of AF, LAA remodelling and thrombus formation. Therefore, we planned a prospective study to investigate: (1) serum level of Gal-3, (2) the morphologic and functional remodelling of LAA, (3) the association between Gal-3 and LAA remodelling, and (4) the potential of Gal-3 as a biomarker, to predict the occurrence of LAA thrombus in AF patients.

Material and Methods

Study Population

Our clinical study complied with the declaration of Helsinki and was approved by the hospital ethnics review board of the Shanghai Ninth People's Hospital, Shanghai Jiao Tong University School of Medicine. Individual permission was obtained from all the participants using standard informed consent procedure.

A total of 153 consecutive patients with nonvalvular AF at Shanghai Ninth People's Hospital between January 2015 and February 2017 were enrolled in the study. All the patients underwent transthoracic echocardiography (TTE) and transoesophageal echocardiography (TEE) examinations. Among them, 58 patients had paroxysmal AF. Fifty-five (55) patients had persistent AF with duration longer than 1 month but less than 1 year. Forty (40) patients had permanent AF with duration longer than 1 year. We excluded patients with significant valvular heart disease, acute coronary syndrome, hepatic or renal failure (creatinine clearance <30 mL/min), and chronic inflammatory or neoplasic diseases. Patients undergoing urgent surgery and those with a previous history of pacemakers, infectious endocarditis or cardiac surgery were also excluded.

Echocardiographic Studies

Transthoracic echocardiography was performed using Philips iE Elite ultrasound instrument (Philips Medical Systems, Koninklijke, Netherlands) equipped with S5-1 probe. Standard echocardiographic views were obtained according to the recommendations of the American Society of Echocardiography [8]. Left atrial (LA) and left ventricular (LV) dimensions, wall thickness and left ventricular ejection fraction (LVEF) were measured in the parasternal long axis view using two-dimensional (2D) methods. LA volume was measured using the biplane Simpson method in the apical four- and two-chamber views by X-plane imaging. Mitral inflow velocities were recorded by standard pulsed-wave Doppler with the sample volume placed at the tip of the mitral valve leaflets from the apical four-chamber views. Tissue Doppler-derived peak LV relaxation velocities were measured from the lateral and septal corners of the mitral annulus during early (e') and late (a') diastolic phases of the cardiac cycle at a sweep speed of 100 mm/s. E/e' was calculated as E divided by the average of septal and lateral e' velocity.

Transoesophageal echocardiography was performed immediately after TTE using a 3D matrix-array transoesophageal X7-2t transducer (Philips Medical Systems, Koninklijke, Netherlands). Left atrial appendage images were obtained from the base of the heart with rotation of the probe between 0° and 180°. Blood stasis was quantified by LAA flow velocities. It was measured with pulsed-wave Doppler with the sample volume placed 1 cm distal from the mouth of the appendage in the basal short-axis view from the transverse scan (45° views). LAA emptying flow velocities were measured as the average of five consecutive cardiac cycles. Measurement of LAA orifice diameter and depth was obtained in four TEE views, as shown in Figure 1. The orifice was measured at 0 degrees from the left coronary artery to a point 2 cm from tip of the left upper pulmonary vein limbus. Then it was measured at 45, 90, and 135 degrees from the top of the mitral valve (MV) annulus to a point 2 cm from tip of the left upper pulmonary vein (LUPV) limbus. The average of these measurements was defined as the orifice diameter. LAA depth was determined by measuring the maximum distance from the orifice line to the apex of the LAA. All values mentioned above were measured blindly in five consecutive cardiac cycles by two echocardiogram experts, and the average values were calculated. Spontaneous echo contrast (SEC) was visually classified into four grades by careful attention to the gain settings adjusted. The severity of SEC was scored as follows: 0: absence of echogenicity; 1+: mild (minimal echogenicity detectable only a part of the LA cavity with high gain settings); 2+: moderate (denser swirling during the entire cardiac cycle); and 3+: severe (intense echo density and very slow swirling patterns in the LAA usually with similar density in the main cavity) as defined in a previous report [9].

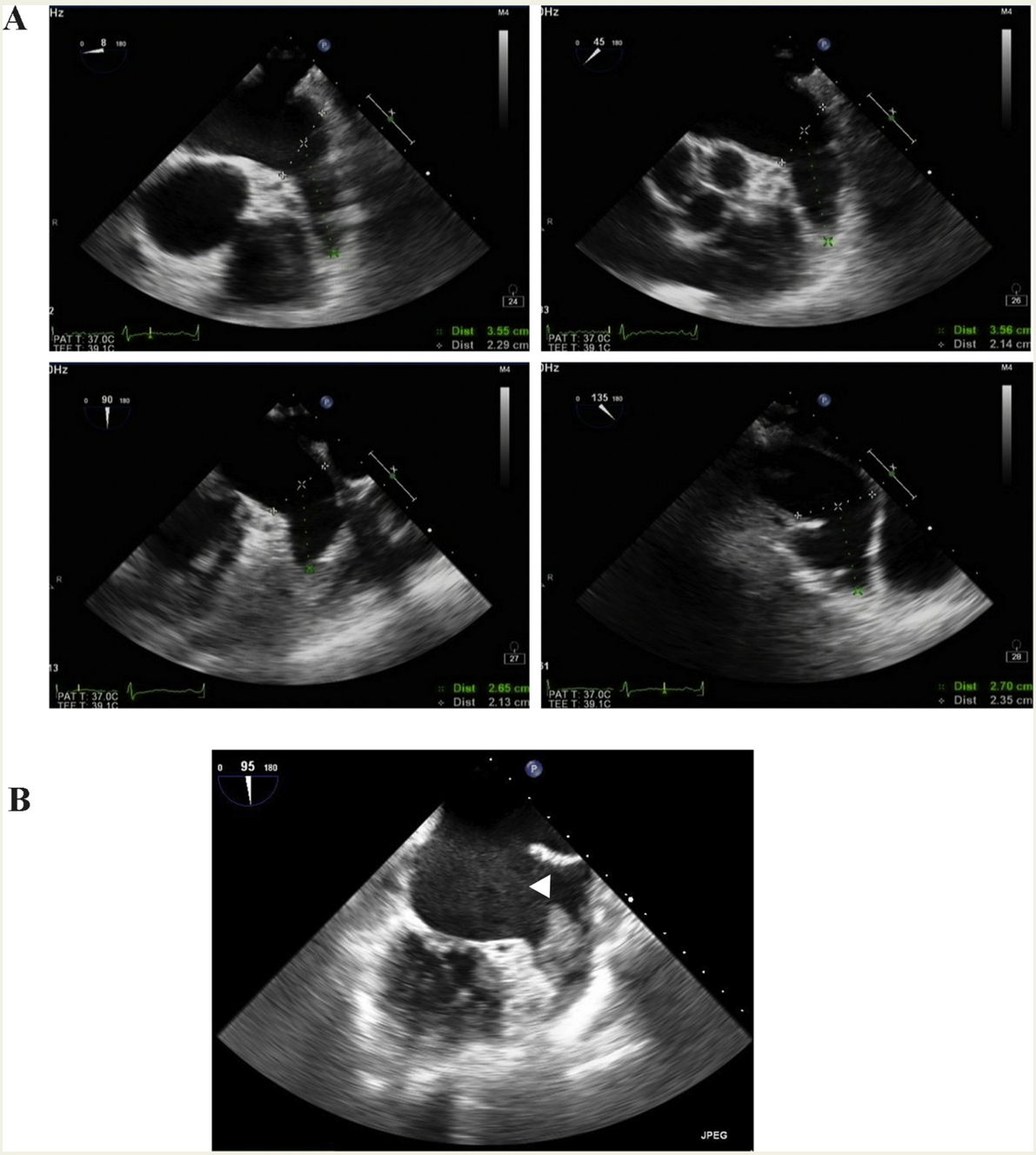

Figure 1 Schematic representation of definition of measurements of transoesophageal echocardiography images of left atrial appendage (LAA) (A) and representative image of LAA thrombus (B). Orifice diameter and LAA depth were analysed in at least four transoesophageal echocardiography (TEE) views (0, 45, 90 and 135 degree). The average of the orifice measurements was defined as the orifice diameter and the maximal distance from the orifice line to the apex was regarded as the LAA depth. White arrow indicates LAA thrombus.

Blood Samples and Laboratory Assays

Venepuncture was performed within 24 hours of admission with the patients fasting for >12 hours. Plasma fractions were obtained by centrifugation for 15 minutes at $3500 \times g$. Aliquots were stored at $-80\,^{\circ}C$ to allow batch analysis in a blinded fashion. Gal-3 levels were determined in defrosted serum samples by ELISA (Enzyme-Linked immunosorbent Assay) (R&D systems, Minneapolis, MN, USA). The inter-assay and intra-assay coefficients of variation were 6.1% and 3.6%, respectively.

Statistical Analysis

Continuous variables were expressed as mean $\pm$ SD, and were compared using one-way ANOVA, as appropriate.

When data were not normally distributed, they were expressed as median and range, and analysed with non-parametric methods. Categorical variables were expressed as percentages and compared using the chi-square-test. Correlation between two continuous variables was examined by Pearson correlation coefficient testing. Multiple linear regression analysis was used to assess correlations between Gal-3 and LA or LAA parameters. Logistic regression analyses were performed to assess the predictive variables for LAA thrombus formation. Areas under the ROC curve for Gal-3 related to LAA thrombus were conducted. P values < 0.05 were considered significant. All analyses were performed using SPSS version 19.0 software package (IBM Corp, Armonk, NY, USA).

Results

Baseline Characteristics

Of the 153 enrolled patients, 58 patients had paroxysmal AF, 55 had persistent AF and 40 had permanent AF. Their baseline clinical characteristics are presented in Table 1. There were no significant differences among patients with different types of AF in the most of baseline clinical characteristics. However, patients with persistent or permanent AF had notably higher CHA_2DS_2VASc score, and greater proportion of previous stroke, elevated BNP levels in comparison to those with paroxysmal AF. Use of oral anticoagulants was also higher in patients with either persistent or permanent AF. Oral anticoagulants included warfarin, dabigatran etexilate and rivaroxaban. There were no differences in the remaining medications.

Echocardiographic Characteristics

As shown in Table 2, significant differences were found in LA and LV parameters among patients with different types of AF, including the greatest LA dimension, LA volume and left ventricular end diastolic diameter (LVEDD) especially in patients with permanent AF. However, there were no significant differences between patients with persistent and permanent AF in terms of LA EF, LV EF and E/e'.

Left atrial appendage morphology and function were assessed by TEE (Table 2). Overall, there were significant differences in LAA morphology and function among patients with paroxysmal, persistent or permanent AF. Patients with either persistent or permanent AF had greater LAA orifice diameter and depth, as well as more severe SEC than those with paroxysmal AF. Their LAA flow velocity and tissue Doppler contracting velocity were significantly lower than those in the population with paroxysmal AF. However, there were no significant differences between patients with persistent and permanent AF in parameters reflecting LAA morphology and function except for LAA depth. Furthermore, LAA thrombus was observed in 22 patients (2 in patients with paroxysmal AF, 11 in patients with persistent AF and 9 in patients with permanent AF). Patients with persistent (20%) or permanent AF (22.5%) had a significantly higher prevalence of LAA thrombus than those with paroxysmal AF (3.45%, both $p < 0.01$).

Table 1 Baseline clinical characteristics and findings.

	Paroxysmal AF (n = 58)	Persistent AF (n = 55)	Permanent AF (n = 40)	P-value
Age, year	66.1 ± 9.6	67.4 ± 9.3	70.3 ± 6.9	0.08
Male gender, n(%)	27(46.6%)	30(54.5%)	22(55.0%)	0.62
BMI, kg/m^2	23.16 ± 3.06	23.35 ± 2.11	23.62 ± 2.04	0.68
eGFR, mL/min	59.91 ± 11.91	58.09 ± 9.40	55.95 ± 10.67	0.20
Hypertension, n(%)	29(50%)	32(58.2%)	23(57.5%)	0.63
Dyslipidaemia, n(%)	18(31.0%)	21(38.2%)	9(22.5%)	0.27
Diabetes mellitus, n(%)	11(19.0%)	14(25.5%)	11(27.5%)	0.57
Hyperuricaemia, n(%)	12(20.7%)	16(29.1%)	8(20.0%)	0.48
Previous stroke, n(%)	4(6.9%)	12(21.8%)*	14(35.0%)*	$p < 0.01$
Use of statin, n(%)	17(29.3%)	24(43.6%)	18(45.0%)	0.18
Use of ACEI/ARB, n(%)	20(34.5%)	23(41.8%)	16(40.0%)	0.71
Use of antiarrhythmic drugs, n(%)	50(86.2%)	46(83.6%)	37(92.5%)	0.44
Use of OAC, n(%)	10(17.2%)	25(45.5%)*	24(60.0%)*	$p < 0.01$
CHA_2DS_2VASc	1.79 ± 1.04	2.95 ± 1.28*	3.40 ± 1.26*	$p < 0.01$
AF at the examination, n(%)	9(15.5%)	0(100%)*	0(100%)*	$p < 0.01$
BNP (pg/ml)	306.56 ± 156.90	586.62 ± 198.73*	622.55 ± 267.68*	$p < 0.01$

Abbreviations: BMI, body mass index; ACEI, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker; OAC, oral anticoagulant drugs; BNP, B-type natriuretic peptide; AF, atrial fibrillation.

*$p < 0.05$, vs. patients with paroxysmal AF.

Table 2 Measurements on transthoracic echocardiography and transoesophageal echocardiography.

	Paroxysmal AF (n = 58)	Persistent AF (n = 55)	Permanent AF (n = 40)
LA diameter, mm	37.45 ± 4.32	39.84 ± 5.17*	44.52 ± 4.85*,**
LA volume, ml	71.52 ± 21.04	90.62 ± 36.26*	151.73 ± 61.80*,**
LA ejection fraction, %	45.16 ± 7.15	39.16 ± 9.80*	34.33 ± 9.60*
LVEDD, mm	47.05 ± 5.22	46.55 ± 6.50	54.33 ± 6.89*,**
LV ejection fraction, %	57.90 ± 7.82	52.4 ± 7.10*	51.90 ± 7.09*
E/e′	7.51 ± 1.37	9.07 ± 1.41*	9.58 ± 1.45*
LAA orifice diameter, mm	20.29 ± 3.63	22.18 ± 4.44*	23.08 ± 4.99*
LAA depth, mm	28.46 ± 4.84	28.28 ± 6.70	31.61 ± 5.51*,**
LAA flow velocity, cm/s	38.88 ± 10.88	30.79 ± 11.78*	29.93 ± 9.80*
LAA tissue Doppler velocity, cm/s	9.93 ± 2.45	8.84 ± 2.10*	8.32 ± 1.94*
Degree of SEC	0.33 ± 0.78	1.05 ± 1.41*	1.11 ± 1.28*
LAA thrombus, n (%)	2(3.45)	11(20)*	9(22.5)*

Abbreviations: LA, left atrial; LAA, left atrial appendage; LV, left ventricular; LVEDD, left ventricular end diastolic diameter; SEC, spontaneous echo contrast; AF, atrial fibrillation

*$p < 0.05$, vs. patients with paroxysmal AF.

**$p < 0.05$, vs. patients with persistent AF.

Serum Levels of Gal-3 in Patients With AF

As shown in Figure 2A, we observed significant differences in the serum levels of Gal-3 among patients with different types of AF. Patients with persistent AF (16.99 ± 5.49 ng/ml, $p < 0.01$) or permanent AF (19.59 ± 6.95 ng/ml, $p < 0.01$) had higher levels of Gal-3 than those with paroxysmal AF (13.21 ± 2.98 ng/ml). The greatest levels of Gal-3 were obtained in a population with permanent AF ($p = 0.018$).

Association of Gal-3 With LAA Echocardiographic Parameters

To assess the association of Gal-3 with LA function, LAA remodelling and LAA thrombus, we performed multivariate analysis. It was found that high levels of Gal-3 were closely correlated with decreased LAA flow velocity ($p = 0.022$) and occurrence of LAA thrombus ($p < 0.01$) (Table 3). Multivariate analysis also displayed significant correlation between the level of Gal-3 and impaired LA function (LA volume and LA EF, but not LA diameter) (Table 3).

As E/e′ ration is a marker of LV diastolic function, we then investigated the relationships between E/e′ and Gal-3 or LA function measured by TTE. A positive correlation was observed between the level of Gal-3 and E/e′ by Pearson's test ($r = 0.551$, $p < 0.01$). An inverse correlation between E/e′ and LA EF ($r = -0.545$, $p < 0.01$) as well as a positive correlation between E/e′ and LA diameter ($r = 0.482$, $p < 0.01$) or LA volume ($r = 0.508$, $p < 0.01$) were documented.

Risk Factors for LAA Thrombus

Logistic regression analysis was performed in two models to identify the independent predicators of LAA thrombus in AF patients (Table 4). Model 1 included clinical variables with a p value ≤0.10 in univariate analysis. Model 2 included conventional LAA echocardiographic parameters. Gal-3 was excluded from Model 2 because there was a strong correlation between Gal-3 and LAA echocardiographic parameters. In multivariate logistic analysis, Gal-3 (OR 0.404, 95% CI 0.184–0.889, $p = 0.024$) was identified as an independent determinant for presence of LAA thrombus, as were CHA_2DS_2VASc score (OR 0.091, 95% CI0.008–0.981, $p = 0.048$), LAA depth (OR 1.606, 95% CI 1.050–2.457, $p = 0.029$), and LAA tissue Doppler contracting velocity (OR 0.025, 95% CI 0.001–0.511, $p = 0.017$). Moreover, ROC analysis identified the optimal cut-off value of Gal-3 as 18.95 ng/ml for predicting LAA thrombus formation with sensitivity 90.9% and specificity 96.9% (Figure 2B).

Discussion

The present study investigated the serum levels of Gal-3, a marker of LAA interstitial fibrosis and LAA remodelling in patients with paroxysmal AF, persistent AF and permanent AF. Our findings are summarised as follows: (1) Serum levels of Gal-3, LAA morphology and function were significantly different among patients with different types of AF; (2) Patients with persistent or permanent AF had significantly higher levels of Gal-3, greater LAA morphologic parameters (orifice diameter and depth) and worse LAA function (emptying flow velocity and tissue Doppler contracting velocity) in comparison to patients with paroxysmal AF; (3) The levels of Gal-3 was one of independent predictors of LAA thrombus formation. Therefore, we propose that Gal-3 may provide additional risk stratification in AF, as well as CHA_2DS_2VASc score, LAA depth, and LAA tissue Doppler contracting velocity, which are other well-defined risk factors of LAA thrombus.

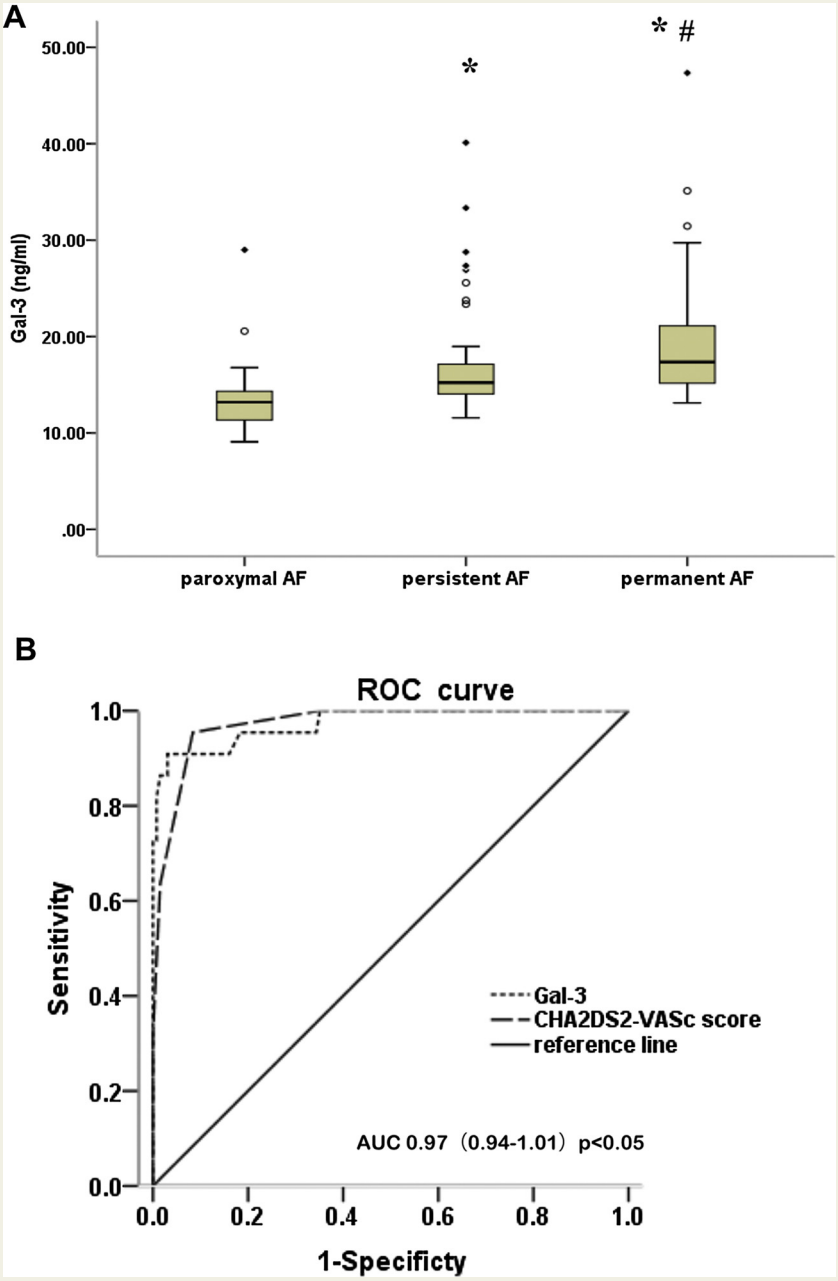

Figure 2 Alterations of serum level of Gal-3 in patients with different types of atrial fibrillation (AF) (A) and Receiver Operating Characteristic (ROC) for evaluation of Galectin (Gal)-3 level related to left atrial appendage (LAA) thrombus (B). *p < 0.05, vs. patients with paroxysmal AF; #p < 0.05, vs. patients with persistent AF.

Numerous studies have explored whether LA and LAA undergo significant alterations in structure and function as AF progresses, such as increase in LA/LAA volume and decrease in LA/LAA contractility [2,3,10,11]. In accordance with these findings, we found that patients with persistent or permanent AF had higher LA volume, greater LAA orifice diameter and depth, and less LA/LAA contraction than those with paroxysmal AF. However, there were no significant differences in most echocardiographic parameters between persistent and permanent AF except for LA diameter, LA volume and LAA depth. Our observations suggested that, in addition to alterations in LA size, LAA morphologic parameters for assessing depth but not orifice diameter further increased during the progression of AF from persistent to permanent types. Functions of LAA were comparably low in persistent AF and permanent AF but relatively well preserved in paroxysmal AF.

Next, we explored the correlation between echocardiographic parameters reflecting LAA remodelling and thrombus formation in AF patients. By multivariate analysis, we found that LAA depth and decreased LAA flow velocity were independent determinants of LAA

Table 3 Multivariate linear regression analysis for the association between Gal-3 and LA or LAA parameters in AF patients.

	B-coefficients	95% CI for B	P-value
LA parameters measured by TTE			
LA diameter, mm	0.074	−0.101–0.248	0.410
LA volume, ml	0.058	0.038–0.077	<0.01
LA ejection fraction, %	−0.120	−0.202 to −0.037	<0.01
LAA parameters measured by TEE			
LAA diameter, mm	0.114	−0.064–0.292	0.207
LAA depth, mm	−0.031	−0.154–0.091	0.614
LAA flow velocity, cm/s	−0.093	−0.172 to −0.134	0.022
LAA tissue Doppler velocity, cm/s	−0.114	−0.442–0.214	0.494
Degree of SEC	−0.964	−2.168–0.241	0.116
LAA thrombus	−12.925	−16.200 to −9.651	<0.01

Abbreviations: TTE, transthoracic echocardiography; TEE, transoesophageal echocardiography; LA, left atrial; LAA, left atrial appendage; SEC, spontaneous echo contrast; AF, atrial fibrillation.

thrombus. In the present study, LAA depth seems to play a more essential role in risk stratification of cardiogenic stroke compared with other morphologic measurements of LAA, for example orifice diameter. It may be due to the observations obtained in this study that LAA depth, but not orifice dimension, kept on increasing during the progression of AF. Furthermore, various studies have evaluated the value of LAA echocardiographic parameters in predicting thrombus formation and cardiogenic stroke [12–16]. Left atrial appendage morphologic elements (orifice dimension or area, depth, LAA volume, non-chicken wing type LAA and the number of LAA lobes) and contractility (LAA EF, flow velocity and tissue Doppler velocity) are proposed to be useful to evaluate the risk for cardiogenic stroke. However, which is the optimal factor for cardiogenic stroke risk stratification remains controversial because of the complexity and variability of LAA anatomy and haemodynamic status.

Cardiac fibrosis and heart failure are well-established consequences of AF [1]. Fibrosis has been proposed to be strongly associated with appendage thrombus and cardiogenic stroke in AF [17,18]. Therefore, the present study investigated the role of Gal-3, a potential biomarker of atrial fibrosis in risk assessment of AF and its complications. We found that the serum level of Gal-3 significantly increased in persistent AF or permanent AF in comparison to paroxysmal AF and that high levels of Gal-3 were closely correlated with LA and LAA remodelling evaluated by echocardiogram. Moreover, multivariate logistic regression analysis revealed that the serum levels of Gal-3 was identified as a novel risk factor for the formation of LAA thrombus in AF patients, as well as CHA_2DS_2VASc score, LAA depth and LAA tissue Doppler velocity. Gal-3 >18.95 ng/ml was the cut-off point for predicting LAA thrombus formation with sensitivity 90.9% and specificity 96.9%. Collectively, Gal-3 may be a potential biomarker to assist risk stratification and prediction

Table 4 Multivariate logistic regression analysis for LAA thrombus in AF patients.

	Odds ratio	95% Confidential interval	P-value
Variables (Model 1)			
Gal-3, ng/ml	0.404	0.184–0.889	0.024
BNP, pg/ml	0.999	0.988–1.011	0.947
CHA2DS2VASc	0.091	0.008–0.981	0.048
Previous stroke	0.007	0.000–6.653	0.156
Variables (Model 2)			
LAA diameter, mm	1.195	0.836–1.707	0.328
LAA depth, mm	1.606	1.050–2.457	0.029
LAA flow velocity, cm/s	0.703	0.48–1.026	0.068
LAA tissue Doppler velocity, cm/s	0.025	0.001–0.511	0.017

Abbreviations: LAA, left atrial appendage; Gal, galectin, BNP, brain natriuretic peptide, AF, atrial fibrillation.

of prognosis in AF, as it can be measured by fully-automated immunoassays with satisfactory analytical performance, high throughput and reduced turnaround time [19,20].

Lippi et al. reviewed recent studies to analyse the epidemiological and/or biological correlation between Gal-3 and AF [21]. Most studies supported the role of Gal-3 in AF [22–25] and suggest that serum Gal-3 is a useful predictor of impaired heart function and heart structure remodelling in patients with AF [6,25,26]. The epidemiological results linking Gal-3 with AF were also supported by biological evidence. It has been suggested that conventional AF risk factors (e.g., hypertension, coronary artery disease and diabetes mellitus) stimulate the release of Gal-3 from macrophages, which, in turn, promotes the accumulation and activation of inflammatory cells in cardiac tissue, but also induces fibroblast activation and proliferation, thus resulting in cardiac remodelling and fibrosis, myocardiocyte dysfunction and eventually predisposing to AF [21]. Onset of AF further magnifies macrophage activation, thus initiating a vicious cycle that is reliably reflected by the findings that serum levels of Gal-3 dramatically increase in patients with new onset AF in contrast to those with preexisting, chronic type [27].

Study Limitations

There were several limitations of our study. First, this is an observational study with a small number of patients in a single centre. A larger scale multicentre study is desirable. Second, some patients who had particularly complex LAA structures, such as several lobes, were very difficult to assess by TEE. Multislice computed tomography or magnetic resonance imaging synchronised with echocardiogram may provide more supporting results. Finally, although we investigated the association of Gal-3 with LAA thrombus, we cannot draw a conclusion regarding the predictive value of Gal-3 for estimating the occurrence of thromboembolic events. Because thromboembolism events are affected by numerous factors such as age, hypertension and diabetes mellitus, it is possible that presence of LAA thrombus does not always predict the occurrence of cardiogenic thromboembolism. A prospective study in a larger population is desired to validate the prognostic value of Gal-3 on long-term outcome.

Conclusion

We demonstrate that as AF progresses, LAA undergoes remodelling in morphology and function along with an increase in serum levels of Gal-3. The level of Gal-3 is closely linked with LAA remodelling caused by AF. This parameter is also proposed to be one of the independent predictors of LAA thrombus among various clinical and echocardiographic parameters. Gal-3 might be an effective biomarker for aiding risk stratification and prognostic prediction in the AF population.

Acknowledgements

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