

Left Atrial Deformation And Risk of Transient Ischemic Attack And Stroke In Paroxysmal Atrial Fibrillation

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Abstract

Left atrial (LA) remodeling is closely related to cerebral stroke, but the relationship between impaired deformability of LA in early stages and stroke/TIA is not clear. The aim of this study was to evaluate the changes of LA deformability and its relationship with stroke/TIA events by using Speckle Tracking echocardiography. In 365 patients with paroxysmal atrial fibrillation (AF) (318, Non stroke/TIA; 47, stroke/TIA), comprehensive echocardiography was performed by using speckle tracking imaging to calculate mean LA longitudinal strain and strain rate values from apical four chamber view, apical two chamber view and apical three cavity view. The patients in stroke/TIA group had greater ages, a greater proportion of men and lower LA strain rate during left ventricular (LV) early diastole (SRE), and the difference was statistically significant ($p < 0.05$). In the univariate linear regression analysis, the following clinical and conventional echocardiographic parameters each had a significant linear correlation with SRE ($p < 0.001$), they were E/A ratio, LA volume index, body mass index, mean E/e', LV ejection fraction, age, proportion of hypertension. Through a multiple linear regression analysis, the results show that there is a linear dependence between SRE and E/A ratio, LA volume index and Body mass index.

The regression equation is $y = -1.430 - 0.394X_1 + 0.012X_2 + 0.019X_3$ ($p < 0.001$) (y, SRE; X_1 , E/A ratio; X_2 , LA volume index; X_3 , Body mass index). In the multivariate logistic regression analyses, SRE and Sex ratio were independently risk factors stroke/TIA. (SRE, OR 2.945, 95% CI 1.092-7.943, $p = 0.033$; Sex, OR 0.462, 95% CI 0.230-0.930, $p = 0.031$)

In patients with paroxysmal AF, SRE could reflect the impaired deformability of LA in early stages, and it was associated with the risk of stroke/TIA.

Introduction

Stroke is a kind of serious complication in patients with atrial fibrillation (AF). The reason for this is that atrial fibrillation causes a rise in left atrial pressure, whereas long-term left atrial pressure causes progressive left atrial remodeling^[1]. But more studies had confirmed that there was an obvious correlation between left atrial (LA) function changes and LA remodeling^[2, 3]. Because LA remodeling could lead to reduce atrial wall contraction force, prolong the time which blood flow through LA; thereby it would cause atrial wall fibrosis, atrial wall mechanical and electrical conduction abnormalities, and ultimately lead to LA enlargement, blood stasis and thrombosis formation^[4, 5].

It was proved to be effective to assess LA remodeling and function by using LA longitudinal strain, the effect is better than that of conventional ultrasound echocardiography parameters such as LA volume index; and the former could more accurately evaluate LA reservoir function, conduit function and pump function. And as a non-invasive examination, its operation was simple and had better repeatability for an experienced echocardiographic operator, so it had a good application prospects^[6, 7].

The present study was designed to measure LA conventional echocardiography and LA strain and strain rate parameters in patients with paroxysmal atrial fibrillation, then to analyze the difference between stroke/ transient ischemic attack (TIA) and non-stroke/TIA patients, and to explore relationship between the impaired deformability of LA and stroke/TIA events and its predictive value for stroke/TIA events.

Methods

Study Population

Of the 385 patients 365(94.8%) were confirmed with high quality speckle tracking LA strain imaging. The study enrolled 365 consecutive patients (222 were male, 58.95±10.52 years old) who underwent pre-procedural transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE) before radiofrequency catheter ablation (RFCA) for symptomatic drug-refractory paroxysmal AF in Beijing Anzhen Hospital Atrial fibrillation center, Capital Medical University from January 2017 to June 2020. 47 patients of them were found to have had a history of ischemic stroke or TIA. The exclusion criteria were as follows: (1) persistent or permanent AF; (2) AF with rheumatic valvular disease; (3) previous history of valve repair or replacement; (4) Echocardiography measurement of left ventricular (LV) EF less than 50%; (5) prior AF ablation; (6) any mitral valve disease, including mild-degree disease. All patients provided proper written informed consent.

We divided the patients into two groups according to the history of stroke/TIA in each patient to evaluate the difference of echocardiography data especially for LA strain and strain rate and try to filter out the best predictive parameters. Ischemic stroke was confirmed by a focal neurological deficit of sudden onset and magnetic resonance imaging or Computerized Tomography findings and TIA was defined as sudden-onset focal neurologic symptoms or signs that resolved within 24 hours.

The study was approved by The Ethical Committee of Beijing Anzhen Hospital, Capital Medical University.

Conventional Transthoracic Echocardiography (TTE)

All subjects underwent comprehensive TTE study using a Vivid 7 or Vivid E9 cardiovascular ultrasound system (GE Medical Systems, Horten, Norway), equipped with a S51 phased-array sector probe (2.5 to 3.5MHz). Standard M-mode, 2-dimensional, and Doppler images were acquired in the parasternal and apical views. Left ventricular (LV) ejection fraction was calculated using the biplane Simpson's rule. The LV diastolic function was assessed by mean E/e', E/A and LA volume index. Tissue Doppler imaging was performed to measure myocardial velocities. Pulsed sample volume was placed at both septal corner and lateral wall of mitral annulus; early diastolic (e') and late diastolic (a') myocardial velocities were recorded. The mean E/e' ratio was then calculated. All measurements were recorded as average of three cardiac cycles according to the standards of American Society of Echocardiography guidelines^[8, 9].

Speckle Tracking Echocardiography

Each patient was collected LA velocity vector imaging data, the standard gathering sections were apical four chamber view, apical two chamber view and apical three cavity view, each section was set to acquire three cardiac cycles and frame rate is adjusted to more than 60 frames per second. The analysis was performed offline using workstation software (EchoPAC PC; GE Medical Systems). LA strain was set to zero at the beginning of the P wave (P-triggered analysis). After manual tracing of the endocardial LA borders, an epicardial surface tracing was automatically generated by the system, creating a region of interest, which was automatically determined, and speckles were traced frame by frame. The region of interest was divided into 6 segments and the averages of the values and curves of strain and strain rate in the longitudinal direction for each segment were generated automatically. The LA roof segments in each view were excluded in this study due to the discontinuity of LA wall because of the connection to the pulmonary veins. Segments with suboptimal image were rejected by the software and excluded from the analysis. By calculating the average strain and strain rate of left atrium in the four-chamber, two-chamber and three-chamber view, we got the mean longitudinal strain and mean longitudinal strain rate of LA.

The LA strain versus time curves were measured respectively, as the positive peak strain during LV systole is LA strain during LV systole (SS) and negative peak strain during LV diastole is LA strain during LV diastole (SD), the distance between the two peaks is the global longitudinal strain (GLS) of LA (**Figure 1**); and for the LA strain rate versus time curves, the positive peak in the middle during LV systole indicates LA strain rate during LV systole (SRS), the negative peak on the right side indicates LA strain rate during LV early diastole (SRE) and the another negative peak on the left side indicates LA strain rate during LV late diastole (SRL) (**Figure 2**).

Inter- and Intraobserver Variability

To detect the variation between the observer and the observer, we randomly selected 15 patients to measure the LA strain and strain rate; first, measurements were repeated twice by one observer, then two experienced observers who were unaware of each other's measurements and of the study time point obtained VVI data from the same patients.

Statistical Analysis

Continuous data are expressed as mean \pm SD. Categorical data are summarized as frequencies and percentages. Continuous variables were compared using the Student *t* test (for two groups of comparisons) and ANOVA (for multiple group comparisons). Categorical variables were compared using chi-square test. Univariate and multivariate logistic regression analyses to determine risk factors of stroke/TIA in patients with paroxysmal AF. Statistical analyses were performed using SPSS version 23.0 (SPSS, Inc, Chicago, IL). All P values reported are from two-sided tests, and P values < 0.05 were considered statistically significant.

Results

Study Population

Table 1 lists the basic clinical and echocardiographic data of all patients according to the patient's history of stroke or TIA. We found that the differences in age, sex, and SRE were statistically significant between the two groups ($p \leq 0.05$). Compared with the none stroke/TIA group, the patients in stroke/TIA group had greater ages, a greater proportion of men and lower SRE. For other clinical descriptive parameters and conventional two-dimensional echocardiographic parameters, there is no statistical difference between the two groups.

The intra-observer variability was 9.6%, 9.7%, 8.5%, 8.8%, 9.0% and 9.1%, respectively, for LA SS, SD, GLS, SRS, SRE and SRL. The corresponding values for the inter-observer variability were 8.7%, 9.1%, 8.5%, 8.0%, 7.9% and 8.4% respectively.

Association Between LA Strain Rate and Clinical Features, Cardiac Structure Deformability and Function Change

Through a univariate linear regression analysis, we found the following clinical and conventional echocardiographic parameters each had a significant linear correlation with SRE ($p < 0.001$), these parameters include E/A ratio, LA volume index, body mass index, mean E/e', LV ejection fraction, age, hypertension. After a parameters optimization, we performed multiple linear regression analysis, the results show that there is a linear dependence between SRE and multiple parameters such as E/A ratio, LA volume index and Body mass index. The regression equation is $y = -3.487 - 0.83X_1 + 0.024X_2 + 0.05X_3 + 0.064X_4 + 0.028X_5$ (y, SRE; X1, E/A ratio; X2, LA volume index; X3, Body mass index; X4, Mean E/e'; X5, Age). The results of the regression analysis are shown in **Table 2**.

The predictive value of conventional ultrasound parameters and strain parameters for stroke events

The results showed that LA volume index, mean LA systolic strain and mean LA SRE were highly sensitive to stroke/TIA events; and LV end-diastolic diameter, Mean E/e' showed good specificity. However, on the whole, the AUC of these indicators is not good in this study (**Table-3**). The probable cause is the relatively small sample size of the stroke group, and although we strictly adhere to inclusion criteria, there is a greater likelihood of bias.

The value of various parameters for risk factors of Stroke/TIA

Table 3 presents the logistic regression analyses for clinical and echocardiographic parameters associated with the presence of stroke/TIA. In the univariate logistic regression analyses, the presence of stroke/TIA was associated with old age ($p < 0.05$), more female gender ($p < 0.05$) and greater LA SRE (the absolute value was close to 0) ($p < 0.001$). In the multivariate logistic regression analyses, LA SRE and Sex ratio were independently risk factors stroke/TIA. (SRE, OR 2.945, 95% CI 1.092-7.943, $p = 0.033$; Sex, OR 0.462, 95% CI 0.230-0.930, $p = 0.031$).

Discussion

In his study we mainly analyzed the changes of LA strain and strain rate in patients with paroxysmal atrial fibrillation by using speckle tracking technique and explored its value in stroke/TIA risk prediction. The main conclusions are: (1) the LA SRE change occurred earlier in patients with paroxysmal AF complicated stroke/TIA events; (2) the LA SRE and the clinical and conventional ultrasound echocardiography parameters significantly related; (3) LA SRE is an independent risk factor for stroke in paroxysmal atrial fibrillation patients.

LA Reservoir Function, Conduit Function, Pump Function and LA Deformability

LA function in the whole cardiac cycle was divided into three phase, storing blood in LV systolic phase, most blood via LA into the LV in early diastolic phase and LA contraction pumping the remaining blood to LV in late LV diastolic phase^[6, 10]. Therefore, in the LA strain rate curve we recorded three different peaks: one positive peak in LV systolic phase and two negative peaks in LV early and late diastolic phase, respectively corresponding to LA reservoir function, conduit function and pump function. As we all know, with respect to strain, theoretically strain rate could reflect the earlier damage of LA deformability due to a combination of time change, which had a higher diagnostic value. First we should determine the L_0 of LA in longitudinal axis when analyzing LA strain rate, similar to LV strain and strain rate analysis, we believe that LA was in L_0 state at the beginning of LA contraction, when ECG is located on the P wave phase^[11].

Compared with the non-stroke group, LA volume index in the stroke/TIA group relative increased, but the difference was not statistically significant, but the LA SRE between two groups appeared obvious difference ($p < 0.05$), which indicating there were no obvious morphological changes in LA, LA Deformability function decreased in the early stages. and LA longitudinal strain did not significantly change too.

Association Between LA SRE and Clinical, Conventional Echocardiographic Parameters

Previous studies have confirmed the presence of significant correlation between LA strain with clinical, conventional echocardiographic parameters^[5, 12-16]. Our study also confirmed this, LA SRE had significant linear correlation with age, BMI, hypertension, LV EF, mean E/e' , LA volume index, E/A ratio respectively ($P < 0.001$), especially showed the best correlation with age. LA SRE not only reflected LA remodeling, but more importantly, it reflected early damage of LA deformability function. It could become a potential ideal indicator for LA function changes in early stages^[12, 17-19].

LA Deformability Parameters and Risk Factors for Stroke/TIA

LA remodeling parameters such as LA volume index has been confirmed to be a risk factor for cardiovascular events, such as stroke, myocardial infarction, atrial thrombosis, recurrence of atrial fibrillation, etc^[20-22]. Because the increased LA pressure and increased volume load would lead to the gradual fibrosis of LA wall, thus making LA reservoir, conduit dysfunction. But before the enlargement of LA and LA deformability capacity was likely to have been damaged, if at this stage we could find an ideal

ultrasound parameter for accurate evaluating LA deformability, so as to make an earlier prediction for the above mentioned cardiovascular events.

Previous studies had confirmed that it was feasible to evaluate LA remodeling and deformability using two-dimensional echocardiographic speckle tracking technology^[5, 7, 23, 24]. Small sample studies showed LA longitudinal strain was a risk factors of stroke/TIA in patients with AF^[6, 13]. In our study it was conformed that LA longitudinal strain rate had changed early compared to LA strain and reflect the damages of deformability of LA earlier.

In this study, we found that LA SRE was indeed an independent risk factor ($p < 0.05$) in patients with paroxysmal atrial fibrillation incidence of stroke by multivariate Logistic regression analysis, the smaller the absolute value of SRE, the greater the risk of stroke/TIA. However, to figure out the specific relationship between the index and stroke/TIA, we still need a long-term follow-up combining with clinical and conventional echocardiographic parameters for further analysis^[25].

Clinical Application

LA strain rate changes reflect the ability of the LA deformability, it changed early than LA remodeling^[26-28], and was more accurate than LA strain, so it was more suitable for screening of patients at an early stage. Because of the noninvasive and easy operation, the speckle tracking technique is becoming more and more mature, we hoped that it would be proved to be a reliable parameter in subsequent studies.

Limitation

First, this was a cross-sectional study, which had not been followed up to evaluate the effectiveness of the risk factors. Second, in this study, we aimed to study the patients with paroxysmal AF, and in further study we need to incorporate non atrial fibrillation patients with or without stroke/TIA, then compare the changes of LA strain rate. Third, our patients all had preserved LV ejection fractions.

Conclusions

LA SRE reflects the deformability changes of LA in early stages. It was an independent risk factor for stroke/TIA in patients with paroxysmal AF, and further studies are needed to include more control and long-term follow-up and evaluate the clinical utility of LA strain rate change in prospective studies.

Abbreviations

LA = left atrial

AF = atrial fibrillation

TIA = transient ischemic attack

LV = left ventricular

TTE = transthoracic echocardiography

TEE = transesophageal echocardiography

RFCA = radiofrequency catheter ablation

SS = strain during LV systole

SD = strain during LV diastole

GLS = global longitudinal strain

SRS = strain rate during LV systole

SRE = strain rate during LV early diastole

SRL = strain rate during LV late diastole

VI = volume index

Declarations

Ethics approval and consent to participate: The study was established, according to the ethical guidelines of the Helsinki Declaration and was approved by the Ethical Committee of Beijing Anzhen Hospital, Capital Medical University.

Consent for publication: Not applicable.

Availability of data and material: Data analyzed during this study are included in this published article.

Competing interests: The authors declare no conflict of interest with respect to this manuscript.

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Authors' contributions:

Dr Jian Chen wrote the main manuscript text included formal analysis, investigation and so on.

Dr Ying Zhao prepared figures 1-2 and data curation.

Dr Yihua He had oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team and had management and coordination responsibility for the research activity planning and execution.

All authors reviewed the manuscript.

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References

1. Vatan MB, Yilmaz S, Agac MT, Cakar MA, Erkan H, Aksoy M, Demirtas S, Varim C, Akdemir R, Gunduz H: **Relationship between CHA2DS2-VASc score and atrial electromechanical function in patients with paroxysmal atrial fibrillation: A pilot study.** *J Cardiol* 2015, **66**(5):382-387.
2. Hryniewicz-Szymanska A, Dluzniewski M, Platek AE, Szymanski FM, Syska-Suminska J, Klos-Szadryn A, Glinka M, Strojek M, Kuciej A, Tomaszewska-Kiecana M: **Association of the CHADS2 and CHA 2DS 2-VASc scores with left atrial enlargement: a prospective cohort study of unselected atrial fibrillation patients.** *Journal of thrombosis and thrombolysis* 2015, **40**(2):240-247.
3. Saha SK, Anderson PL, Caracciolo G, Kiotsekoglou A, Wilansky S, Govind S, Mori N, Sengupta PP: **Global left atrial strain correlates with CHADS2 risk score in patients with atrial fibrillation.** *Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography* 2011, **24**(5):506-512.
4. Dzeshka MS, Lip GY, Snezhitskiy V, Shantsila E: **Cardiac Fibrosis in Patients With Atrial Fibrillation: Mechanisms and Clinical Implications.** *Journal of the American College of Cardiology* 2015, **66**(8):943-959.
5. Kuppahally SS, Akoum N, Burgon NS, Badger TJ, Kholmovski EG, Vijayakumar S, Rao SN, Blauer J, Fish EN, Dibella EV *et al*: **Left atrial strain and strain rate in patients with paroxysmal and persistent atrial fibrillation: relationship to left atrial structural remodeling detected by delayed-enhancement MRI.** *Circulation Cardiovascular imaging* 2010, **3**(3):231-239.
6. Brecht A, Oertelt-Prigione S, Seeland U, Rucke M, Hattasch R, Wagelohner T, Regitz-Zagrosek V, Baumann G, Knebel F, Stangl V: **Left Atrial Function in Preclinical Diastolic Dysfunction: Two-Dimensional Speckle-Tracking Echocardiography-Derived Results from the BEFRI Trial.** *Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography* 2016.
7. Mirza M, Caracciolo G, Khan U, Mori N, Saha SK, Srivathsan K, Altemose G, Scott L, Sengupta P, Jahangir A: **Left atrial reservoir function predicts atrial fibrillation recurrence after catheter ablation: a two-dimensional speckle strain study.** *Journal of interventional cardiac electrophysiology : an international journal of arrhythmias and pacing* 2011, **31**(3):197-206.

8. Lang RM, Badano LP, Mor-Avi V, Afzalpoor J, Armstrong A, Ernande L, Flachskampf FA, Foster E, Goldstein SA, Kuznetsova T *et al*: **Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging.** *European heart journal cardiovascular Imaging* 2015, **16**(3):233-270.
9. Nagueh SF, Smiseth OA, Appleton CP, Byrd BF, 3rd, Dokainish H, Edvardsen T, Flachskampf FA, Gillebert TC, Klein AL, Lancellotti P *et al*: **Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging.** *Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography* 2016, **29**(4):277-314.
10. Guo C, Liu J, Zhao S, Teng Y, Shen L: **Decreased left atrial strain parameters are correlated with prolonged total atrial conduction time in lone atrial fibrillation.** *The international journal of cardiovascular imaging* 2016, **32**(7):1053-1061.
11. Motoki H, Negishi K, Kusunose K, Popovic ZB, Bhargava M, Wazni OM, Saliba WI, Chung MK, Marwick TH, Klein AL: **Global left atrial strain in the prediction of sinus rhythm maintenance after catheter ablation for atrial fibrillation.** *Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography* 2014, **27**(11):1184-1192.
12. Tsai WC, Lee CH, Lin CC, Liu YW, Huang YY, Li WT, Chen JY, Lin LJ: **Association of left atrial strain and strain rate assessed by speckle tracking echocardiography with paroxysmal atrial fibrillation.** *Echocardiography (Mount Kisco, NY)* 2009, **26**(10):1188-1194.
13. Ersboll M, Andersen MJ, Valeur N, Mogensen UM, Waziri H, Moller JE, Hassager C, Sogaard P, Kober L: **The prognostic value of left atrial peak reservoir strain in acute myocardial infarction is dependent on left ventricular longitudinal function and left atrial size.** *Circulation Cardiovascular imaging* 2013, **6**(1):26-33.
14. Longobardo L, Todaro MC, Zito C, Piccione MC, Di Bella G, Oreto L, Khandheria BK, Carerj S: **Role of imaging in assessment of atrial fibrosis in patients with atrial fibrillation: state-of-the-art review.** *European heart journal cardiovascular Imaging* 2014, **15**(1):1-5.
15. Karabay CY, Zehir R, Guler A, Oduncu V, Kalayci A, Aung SM, Karagoz A, Tanboga IH, Candan O, Gecmen C *et al*: **Left atrial deformation parameters predict left atrial appendage function and thrombus in patients in sinus rhythm with suspected cardioembolic stroke: a speckle tracking and transesophageal echocardiography study.** *Echocardiography (Mount Kisco, NY)* 2013, **30**(5):572-581.
16. Obokata M, Negishi K, Kurosawa K, Tateno R, Tange S, Arai M, Amano M, Kurabayashi M: **Left atrial strain provides incremental value for embolism risk stratification over CHA(2)DS(2)-VASc score and indicates prognostic impact in patients with atrial fibrillation.** *Journal of the American Society of Echocardiography : official publication of the American Society of Echocardiography* 2014, **27**(7):709-716.e704.

17. Kupczynska K, Michalski BW, Miskowiec D, Kasprzak JD, Wejner-Mik P, Wdowiak-Okrojek K, Lipiec P: **Association between left atrial function assessed by speckle-tracking echocardiography and the presence of left atrial appendage thrombus in patients with atrial fibrillation.** *Anatolian journal of cardiology* 2017, **18**(1):15-22.
18. Kucuk U, Kucuk HO, Demirkol S, Iyisoy A: **Left atrial deformation parameters predict left atrial appendage function and thrombus in patients in sinus rhythm with suspected cardioembolic stroke: a speckle tracking and transesophageal echocardiography study: left atrial filling and emptying velocities as indicators of left atrial mechanics.** *Echocardiography (Mount Kisco, NY)* 2013, **30**(7):860-861.
19. Verdejo HE, Becerra E, Zalaquet R, Del Campo A, Garcia L, Troncoso R, Chiong M, Marin A, Castro PF, Lavandero S *et al.*: **Atrial Function Assessed by Speckle Tracking Echocardiography Is a Good Predictor of Postoperative Atrial Fibrillation in Elderly Patients.** *Echocardiography (Mount Kisco, NY)* 2016, **33**(2):242-248.
20. Kim D, Shim CY, Hong GR, Kim MH, Seo J, Cho IJ, Kim YD, Chang HJ, Ha JW, Heo JH *et al.*: **Clinical Implications and Determinants of Left Atrial Mechanical Dysfunction in Patients With Stroke.** *Stroke; a journal of cerebral circulation* 2016, **47**(6):1444-1451.
21. Xu TY, Sun JP, Lee AP, Yang XS, Ji L, Zhang Z, Li Y, Yu CM, Wang JG: **Left atrial function as assessed by speckle-tracking echocardiography in hypertension.** *Medicine* 2015, **94**(6):e526.
22. Sanchis L, Montserrat S, Obach V, Cervera A, Chamorro A, Vidal B, Mas-Stachurska A, Bijmens B, Sitges M: **Left Atrial Function Is Impaired in Some Patients With Stroke of Undetermined Etiology: Potential Implications for Evaluation and Therapy.** *Revista espanola de cardiologia (English ed)* 2016, **69**(7):650-656.
23. Spethmann S, Stuer K, Diaz I, Althoff T, Hewing B, Baumann G, Dreger H, Knebel F: **Left atrial mechanics predict the success of pulmonary vein isolation in patients with atrial fibrillation.** *Journal of interventional cardiac electrophysiology : an international journal of arrhythmias and pacing* 2014, **40**(1):53-62.
24. Cameli M, Mandoli GE, Loiacono F, Sparla S, Iardino E, Mondillo S: **Left atrial strain: A useful index in atrial fibrillation.** *International journal of cardiology* 2016, **220**:208-213.
25. Popovic ZB, Cremer PC: **Assessing Diastology in Aortic Stenosis: Should We Stress About Strain Rate?** *JACC Cardiovasc Imaging* 2016, **9**(5):529-531.
26. Li Y, Ding W, Wang H, Song N, Lin L, Wang Z, Zhong M, Zhang Y, Zhang W: **Relationship of CHA2DS2-VASc and CHADS2 score to left atrial remodeling detected by velocity vector imaging in patients with atrial fibrillation.** *PLoS one* 2013, **8**(10):e77653.

27. Saha SK, Kiotsekoglou A: **Speckle tracking-derived mechanical dispersion of left atrial myocardial deformation: An essential parameter in atrial fibrillation management?** *Echocardiography (Mount Kisco, NY)* 2017, **34**(2):159-161.

28. Henein M, Zhao Y, Henein MY, Lindqvist P: **Disturbed left atrial mechanical function in paroxysmal atrial fibrillation: a speckle tracking study.** *International journal of cardiology* 2012, **155**(3):437-441.

Tables

Table 1 Clinical and Echocardiographic Characteristics of patients with paroxysmal AF

Variable	Overall (n = 365)	Non stroke/TIA (n = 318)	Stroke/TIA (n = 47)	<i>p</i>
Clinical characteristics				
Age (years)	58.95±10.52	58.46±10.55	62.32±9.73	0.02
Female gender	143(39%)	131(41%)	12(26%)	0.04
Body mass index (kg/m ²)	25.32±3.77	25.41±3.79	24.71±3.64	0.24
Body surface area (m ²)	1.78±0.19	1.78±0.19	1.77±0.16	0.67
Diabetes mellitus	59(16%)	49(15%)	10(21%)	0.31
Hypertension	200(55%)	171(54%)	29(62%)	0.31
Hyperlipemia(%)	64(18%)	53(17%)	11(23%)	0.26
Coronary heart disease(%)	51(14%)	44(14%)	7(15%)	0.85
Smoking(%)	88(24%)	77(24%)	11(23%)	0.90
Drinking(%)	66(18%)	57(18%)	9(19%)	0.84
Family history of atrial fibrillation(%)	18(5%)	14(4%)	4(9%)	0.39
Conventional two-dimensional echocardiography				
LV end-diastolic diameter(mm)	48.47±3.72	48.50±3.66	48.28±4.16	0.71
LV ejection fraction(%)	65.60±4.99	65.53±4.93	66.04±5.40	0.52
Mean E/e'	9.93±3.42	9.82±3.26	10.63±4.32	0.13
E/A ratio	1.07±0.41	1.08±0.42	1.00±0.35	0.25
LA volume index(ml/m ²)	35.67±12.31	35.44±12.52	37.24±10.72	0.35
Speckle tracking				
mean LA systolic strain(%)	10.87±4.26	10.96±4.35	10.31±3.53	0.33
mean LA diastolic strain(%)	-10.67±3.12	-10.72±3.16	-10.38±2.85	0.49
Global longitudinal strain(%)	21.55±5.57	21.68±5.70	20.69±4.59	0.26
mean LA SRS	1.03±0.27	1.04±0.27	0.98±0.24	0.13
mean LA SRE	-0.93±0.37	-0.95±0.39	-0.83±0.30	0.04
mean LA SRL	-1.31±0.51	-1.33±0.53	-1.20±0.37	0.11

LA SRS, left atrial strain rate during left ventricular systole; **LA SRE**, left atrial strain rate during left ventricular early diastole; **LA SRL**, left atrial strain rate during left ventricular late diastole

Table 2 Univariate and multivariate linear regression for LA SRE in paroxysmal AF

Factor	Univariate			Multivariate		
	R	R ²	<i>p</i>	B	Beta	<i>p</i>
E/A ratio	0.403	0.163	<0.001	-0.830	-0.342	<0.001
LA volume index	0.382	0.143	<0.001	0.024	0.297	<0.001
Body mass index	0.186	0.035	<0.001	0.050	0.188	<0.001
Mean E/e'	0.398	0.158	<0.001	0.064	0.220	<0.001
LV ejection fraction	0.197	0.039	0.003	-	-	-
LVEDD	0.109	0.012	0.037	-	-	-
Age	0.532	0.283	<0.001	0.028	0.291	<0.001

LA SRE, left atrial strain rate during left ventricular early diastole

Table 3 Diagnostic value of conventional ultrasonic parameters and strain parameters.

Parameter	Cut off value	AUC [95% CI]	Sensitivity% [95% CI]	Specificity% [95% CI]	P value
Conventional 2D echo					
LV end-diastolic diameter(mm)	< 42.50	0.5054 [0.4126 to 0.5981]	12.77 [4.832% to 25.74%]	93.71 [90.45% to 96.12%]	0.9057
LV ejection fraction(%)	> 67.50	0.5277 [0.4330 to 0.6224]	40.43 [26.37% to 55.73%]	62.26 [56.69% to 67.61%]	0.5398
Mean E/e'	> 14.95	0.5340 [0.4453 to 0.6227]	14.89 [6.204% to 28.31%]	93.08 [89.71% to 95.61%]	0.4514
E/A ratio	< 1.050	0.5426 [0.4606 to 0.6246]	61.70 [46.38% to 75.49%]	49.06 [43.44% to 54.69%]	0.3455
LA volume index(ml/m ²)	> 27.95	0.5544 [0.4741 to 0.6347]	85.11 [71.69% to 93.80%]	30.82 [25.79% to 36.21%]	0.2286
Speckle tracking					
mean LA systolic strain(%)	< 14.31	0.5268 [0.4432 to 0.6104]	89.36 [76.90% to 96.45%]	21.38 [17.01% to 26.30%]	0.5526
mean LA diastolic strain(%)	> -11.27	0.5417 [0.4561 to 0.6274]	68.09 [52.88% to 80.91%]	44.97 [39.41% to 50.62%]	0.3558
Global longitudinal strain(%)	< 23.28	0.5495 [0.4673 to 0.6317]	78.72 [64.34% to 89.30%]	34.59 [29.37% to 40.10%]	0.2731
mean LA SRS	< 1.025	0.5872 [0.5045 to 0.6700]	72.34 [57.36% to 84.38%]	47.17 [41.58% to 52.82%]	0.05349
mean LA SRE	> -1.085	0.5910 [0.5109 to 0.6712]	87.23 [74.26% to 95.17%]	30.50 [25.49% to 35.89%]	0.04395
mean LA SRL	> -1.305	0.5841 [0.4994 to 0.6687]	68.09 [52.88% to 80.91%]	48.43 [42.81% to 54.07%]	0.06280

Table 4 Univariate and multivariate logistic regression for analyzing risk factors of stroke/TIA

	Univariate			Multivariate		
	B	OR	95% CI	B	OR	95% CI
LA SRS	-1.004	0.366	0.101-1.334	-	-	-
LA SRE	0.988	2.687	1.018-7.090*	1.080	2.945	1.092-7.943*
LA SRL	0.650	1.916	0.908-4.041	-	-	-
GLS	-0.033	0.967	0.913-1.025	-	-	-
Age	0.038	1.038	1.006-1.072*	-	-	-
Sex	-0.715	0.489	0.245-0.978*	-0.771	0.462	0.230-0.930*
Mean E/e'	0.062	1.063	0.981-1.153	-	-	-
LA VI	0.012	1.012	0.987-1.037	-	-	-

LA SRS, left atrial strain rate during left ventricular systole; **LA SRE**, left atrial strain rate during left ventricular early diastole; **LA SRL**, left atrial strain rate during left ventricular late diastole; LA VI, left atrial volume index.

* $p < 0.05$, the difference is statistically significant

Figures

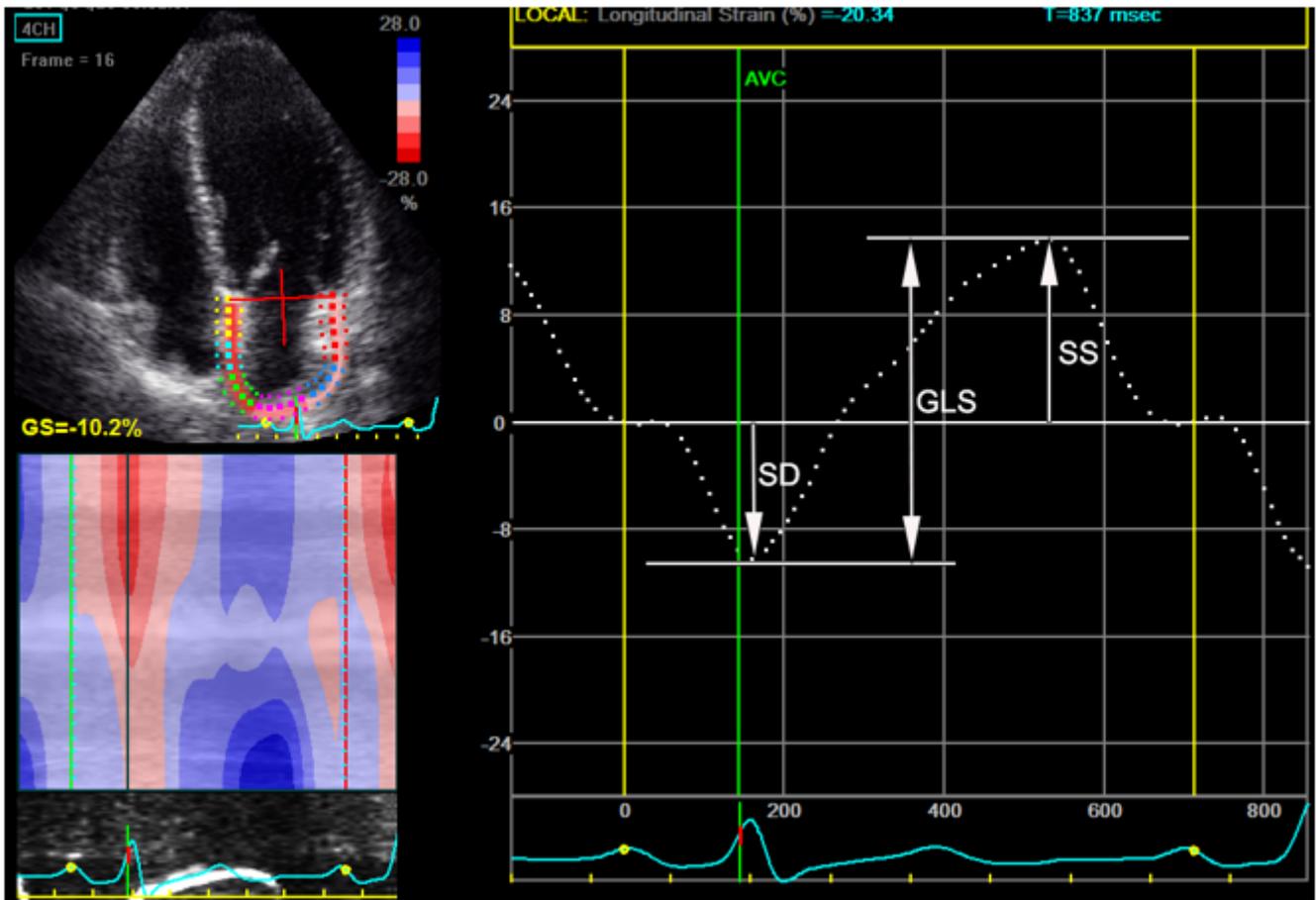


Figure 1

A normal left atrial strain curve in a complete cardiac cycle SS: strain during LV systole; SD: strain during LV diastole; GLS: global longitudinal strain of LA (LA strain was set to zero at the beginning of the P wave)

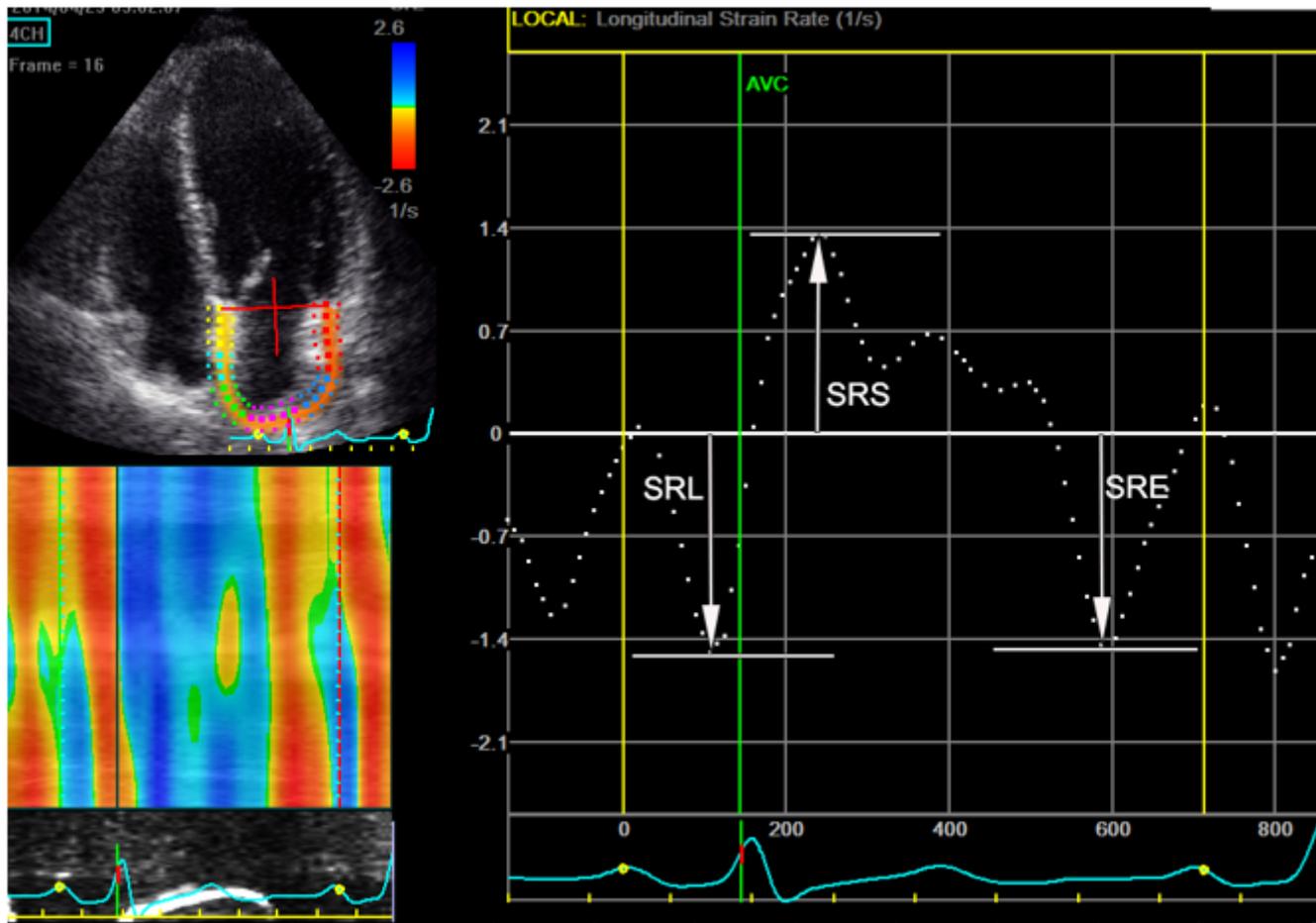


Figure 2

A normal left atrial strain rate curve in a complete cardiac cycle. SRS: strain rate during LV systole; SRE: strain rate during LV early diastole; SRL: strain rate during LV late diastole. (LA strain was set to zero at the beginning of the P wave)