Al-Azhar International Medical Journal

Volume 5 | Issue 4 Article 6

4-30-2024

Section: Cardiology

Predictive Value of Left Atrial Strain Assessed by 2D Speckle Tracking Echocardiography in Development of Post Coronary Artery Bypass Surgery Atrial Fibrillation

Abd El Aziz Rizk Hassan
Cardiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Ahmed Ali Faheem Abdou
Cardiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt

Ahmed Mohamed Abdel Raouf Amer
Cardiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt, drahmadraouf94@gmail.com

How to Cite This Article

Hassan, Abd El Aziz Rizk; Abdou, Ahmed Ali Faheem; and Amer, Ahmed Mohamed Abdel Raouf (2024) "Predictive Value of Left Atrial Strain Assessed by 2D Speckle Tracking Echocardiography in Development of Post Coronary Artery Bypass Surgery Atrial Fibrillation," *Al-Azhar International Medical Journal*: Vol. 5: Iss. 4, Article 6.
DOI: https://doi.org/10.58675/2682-339X.2350

ORIGINAL ARTICLE

Predictive Value of Left Atrial Strain Assessed by 2D Speckle Tracking Echocardiography in Development of Post Coronary Artery Bypass Surgery Atrial Fibrillation

Abd El Aziz R. Hassan , Ahmed A. F. Abdou, . Ahmed M. A. Amer *

Department of Cardiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt.

Abstract

Background: ***Twenty percent to forty percent of individuals undergoing coronary artery bypass grafting develop atrial fibrillation as a complication of the procedure. Over a 6-month follow-up period, left atrial (LA) strain was a reliable predictor of AF recurrence following cardioversion.***

The work aims: ***to assess the relationship between the development of postoperative atrial fibrillation (POAF) in coronary artery bypass grafting (CABG) patients and LA function as assessed by 2D speckle tracking echocardiography.***

Patients and Methods: ***From November 2022 to August 2023, Al-Azhar University Hospital Outpatient Clinics evaluated 50 patients with multivessel coronary artery disease for elective coronary artery bypass surgery.***

Results: ***There was a strong connection between POAF and the LA conduit, the contractile and reservoir strain, the age, the peak A wave, the E/A ratio, the peak E, the E/E ratio, the LA volumes (V max, V min, and pre-A volume), the LA volume index (LAVI), and the LA diameters. There was no statistically significant relation between POAF and demographic data (sex, BMI, BSA, DM, HTN, and smoking), LVIDd, LVIDs, IVSd, PWDd, peak E wave, and E deceleration time.***

Conclusion: ***Speckle tracking echocardiography serves as a reliable, non-invasive tool for assessing atrial mechanical dysfunction in individuals undergoing CABG. This might aid in the detection of patients at high risk for POAF and the avoidance of POAF following CABG.***

Keywords: Atrial fibrillation; LA strain; 2D speckle tracking echocardiography; Post coronary artery bypass surgery

1. Introduction

Twenty percent to forty percent of individuals undergoing CABG surgery develop atrial fibrillation (AF). Hemodynamic impairment, thromboembolic complications, and prolonged hospitalization can all arise from AF. [1]

We should identify those who are more likely to develop POAF so we can take preventative measures.[2] It is also important to identify patients who might benefit from preventative care or close monitoring.[3]

Because the etiology of POAF still needs to be better understood, there is no definite preventive therapy. Proarrhythmia is expected to be caused by a variety of factors, including inflammation, atrial fibrosis, oxidative stress, and alterations in atrial connexin expression. [4]

The LA is crucial to cardiac function. The LA works mechanically in three ways: it holds blood during left ventricular systole; it acts as a passive conduit for blood flow from the pulmonary veins to the left ventricle during early ventricular diastole; and it acts as a booster pump with active LA emptying during late ventricular diastole. [5] People widely use 2D speckle tracking (strain and strain rate) and tissue Doppler imaging (TDI) to detect myocardial dysfunction early and accurately. [6]

Accepted 14 April 2024.
Available online 30 April 2024

* Corresponding author at: Department of Cardiology, Faculty of Medicine, Al-Azhar University, Cairo, Egypt .
E-mail address: mailto:drahmadraouf94@gmail.com (A. M. A. Amer).

https://doi.org/10.58675/2682-339X.2450

In individuals with coronary artery disease, LA enlargement and dysfunction were strong predictors of death. [7]

Doppler-derived strain and strain rate are angle-dependent, whereas 2D strain echocardiography (2DSE) is not. [8]

We have applied Doppler-derived strain imaging to assess LA deformation and evaluate LA function. However, this technique is susceptible to noise artifacts and has restricted reproducibility and angle dependence. [9]

During a 6-month follow-up period, LA strain was a very good indicator of whether AF would return after cardioversion. Patients who stayed in sinus rhythm had better peak atrial longitudinal strain (PALS) than those who had AF return. [10]

This study aims to assess the relationship between the development of POAF in CABG patients and left atrial function as measured by 2D speckle tracking echocardiography.

2. Patients and methods

The outpatient clinic of Al-Azhar University Hospitals evaluated 50 individuals with multivessel coronary artery disease who were candidates for elective CABG surgery from November 2022 to August 2023.

We obtained ethical committee permission and patient-signed informed consent.

2.1.Inclusion criteria: participants who were undergoing elective CABG; sinus rhythm at admission; no history of prior AF attacks; preserved LV systolic function by echocardiography; EF ≥ 50%.

2.2.Exclusion criteria include additional candidates for CABG, such as those with significant valvular lesions or those requiring valve surgery (repair or replacement). Individuals experiencing non-synaptic rhythms, Individuals with a history of AF, those who experienced ACS less than 30 days ago, those suffering from hyperthyroidism or hypothyroidism, those dealing with active inflammatory or infectious diseases, and those suffering from renal impairment or renal failure are also at risk.

2.3.Method

We conducted a full preoperative history taking on all study populations, which included personal history, risk factor history, previous hospitalization and surgical operation history, and drug history. We conducted a clinical examination that included both general and cardiac examinations, as well as anthropometric measurements. We conduct laboratory investigations, analyze 12-lead electrocardiography, take chest X-rays, and perform echocardiography.

A conventional echocardiographic study includes assessment of LV dimensions; an assessment of LV systolic function by conventional echocardiography; and an assessment of LV diastolic function (transmitral flow velocity, mitral annular velocity by tissue Doppler imaging (TDI), LA volumes, and tricuspid regurgitation velocity). [11]

2.4.Left atrial measurements:

The biplane area-length method assesses left atrial volumes from apical two- and four-chamber views by tracing the blood-tissue interface (excluding pulmonary veins and left atrial appendage),[11] LA anteroposterior diameter, LA longitudinal diameter, LA transverse diameter, LA maximal volume, minimal volume, pre-A volume, and LA emptying fraction.

Acquire freeze frames for apical four- and two-chambers 1-2 frames prior to MV opening. Measure the LA volume in dedicated views that maximize the LA length and transverse diameters. We index the volume to the body surface area (BSA) to obtain the LA volume index (LAVI).

LA volumes: 1: We measure the minimal LA volume (Vmin) immediately before the mitral valve closes in the end-diastole. 2: We measure the maximum LA volume (Vmax) immediately before the mitral valve opens in the end-systole. 3: Just before the atrial contraction at the onset of the P wave on the ECG, we measure the Pre-A LA volume (V pre-A).

To determine the left atrial emptying fraction, divide the difference between the maximal and minimal LA volumes by the maximal LA volume. [11]

The assessment of LA functions was conducted using 2D speckle tracking echocardiography.

We used the two-dimensional speckle-tracking echocardiography (STE) technique to quantify LA function, following the steps below: We recorded at least three consecutive beats for each patient, marking the systolic event (mitral valve opening and closing). Semi-automated software traced the LA endocardial border and evaluated the tracing of the six segments. If the program rejects two or more portions, repeat Step 2. Otherwise, the program accepted the research and produced a strain average curve. Additionally, the program used automatic strain software to obtain LA strain curves from both apical 2 automatically- and 4-chamber views, along with values for LASr, LAScd, and LASct, representing the LA reservoir, conduit, and contractile functions, respectively. Additionally, average biplane values were obtained. [12]

We conducted continuous ECG monitoring for 5-7 days and 12-lead ECG every 12 hours during the postoperative follow-up. When symptoms arose, we divided our patients into two groups: the POAF group, which developed POAF, and the NO POAF group, which did not develop POAF.

We used SPSS 24 for statistical analysis. The frequency and percentage of occurrences conveyed qualitative data. The mean of a discrete set of numbers is the sum of the values divided by their number. We reported quantitative data using both the mean and the standard deviation. A statistic known as the standard deviation (SD) can measure the dispersion of a collection of values. A low standard deviation (SD) tends to cluster the values in the set around the set's mean, while a large SD disperses the values across a wider range. We conducted the Chi-square test, the ROC curve, the independent sample T-test, and the probability test (P-value).

3. Results

There was a highly significant (p-value < 0.001) increased age in individuals with POAF (65.1 ± 4.94 years) when compared with patients with no POAF (56.7 ± 5.86 years). No significant relation (p-value > 0.05) between POAF and other examined demographic data (sex, BMI, BSA, DM, HTN, and smoking).Table 1. Correlation between POAF and demographic data in studied patients.

		POAF				STAT. TEST	P-VALUE
		No)N = 37(		Yes)N = 13(			
AGE (YEARS)	Mean	56.7		65.1		T = 4.5	< 0.001
	±SD	5.86		4.94			HS
SEX	Male	29	78.4%	10	76.9%	X^2 =	0.913
	Female	8	21.6%	3	23.1%	0.012	NS
BMI (KG/M²)	Mean	28.0		28.6		T =	0.436
	±SD	2.37		1.89		0.78	NS
BSA (M²)	Mean	1.83		1.78		T = 1.2	0.235
	±SD	0.13		0.08			NS
RISK FACTORS	DM	28	75.7%	11	84.6%	X^2 = 0.44	0.503 NS
	HTN	18	48.6%	10	76.9%	X^2 = 3.1	0.077 NS
	Smoking	22	59.5%	8	61.5%	X^2 = 0.02	0.895 NS

T: independent sample T test.

No significant association could be seen between POAF and any of the LVIDs (p = 0.061), LVIDd (p = 0.061), IVSd (p = 0.408), or PWDd (p = 0.744).

Table 2. Correlation between POAF and LV Measurements in studied patients.

		POAF		T	P-VALUE
		No (N = 37)	Yes (N = 13)		
LVIDD (CM)	Mean	5.14	5.39	1.92	0.061 NS
	±SD	0.43	0.31		
LVIDS (CM)	Mean	3.41	3.5	1.16	0.249 NS
	±SD	0.34	0.18		
IVSD (CM)	Mean	0.92	0.95	0.83	0.408 NS
	±SD	0.12	0.15		
PWDD (CM)	Mean	0.90	0.92	0.32	0.744 NS
	±SD	0.11	0.14		

There was no significant difference as regard peak E wave among patients developed POAF or not (p = 0.215). Those with POAF had a significantly (p=0.008) lower peak A wave (64.8 ± 18 cm/s) compared to those without POAF (79.5 ± 15.7 cm/s). Individuals with POAF had a significantly (p=0.004) higher E/A ratio (1.3 ±0.6) compared to those without POAF (0.9 ±0.3). There is no correlation between POAF and E Deceleration time (p-value = 0.284).

Table 3.Comparison of PW trans-mitral inflow measurements between POAF patients and those without POAF.

		POA F			-VALUE
		o N = 37)	es N = 13)		
PEAK E WAVE CM/S	ean	0.4	6.2	.25	.215 NS
	SD	1.2	0.9		
PEAK A WAVE CM/S	ean	9.5	4.8	.78	.008 S
	SD	5.7	8.0		
E:A RATIO	ean	.9	.3	.01	.004 S
	SD	.3	.6		
E DECELERATION TIME (MS)	ean	61.2	46.5	.08	.284 NS
	SD	5.2	1.5		

There was a highly significant (p-value <0.001) decrease in peak E\` in patients with POAF (5.7±0.8 cm/s) when compared with patients of no POAF (7.2±0.9 cm/s). Statistically significant (p-value=0.001) decrease in peak A\` in patients with POAF (6.6±1.6) when compared with patients of no POAF (8.0±1.2). Highly significant (p-value <0.001) increase in E/E\` in cases with POAF (13.6 ±4.4) when compared with cases of no POAF (9.7 ±1.7).

Table 4. Comparison of Tissue Doppler imaging (TDI) measurements between POAF patients and those without POAF.

		POAF		*T*	*P-value*
		No (N = 37)	Yes (N = 13)		
Peak E\` cm/s	Mean	7.2	5.7	5.4	< 0.001 HS
	±SD	0.9	0.8		
Peak A\` cm/s	Mean	8.0	6.6	3.4	0.001 S
	±SD	1.2	1.6		
E/E\` ratio	Mean	9.7	13.6	4.5	< 0.001 HS
	±SD	1.7	4.4		

There was a highly significant (p-value < 0.001) increase in LA V max in patients with POAF (73.2 ± 12.8 ml) when compared with patients with no POAF (56.9 ± 10.2 ml) and an increase in pre-A volume in patients with POAF (59.8 ± 12.8 ml) when compared with patients of no POAF (41.9 ± 8.3 ml) and increase in V min in patients with POAF (43.1 ± 12.7 ml) when compared with patients of no POAF (25.2 ± 5.4 ml). Also, highly significant (p-value < 0.001) increased LAVI in patients with POAF (41.2 ± 7.4 ml/m2) when compared with patients with no POAF (31.6 ± 6.3 ml/m2).

There was a highly significant (p-value < 0.001) increase in LA anteroposterior diameter (LA APD) in patients with POAF (4.38 ± 0.29 cm) when compared with patients of no POAF (3.88 ± 0.38 cm) and increase in LA transverse diameter (LA TD) in patients with POAF (4.35 ± 0.41 cm) when compared with patients of no POAF (3.9 ± 0.35 cm) and significant (p-value = 0.01) increased LA longitudinal diameter (LA LD) in patients with POAF (5.3 ± 0.4 cm) when compared with patients of no POAF (4.9 ± 0.48 cm).

Table 5. Comparison of LA measurements between POAF patients and those without POAF.

		POAF			*P-value*
		No (N = 37)	Yes (N = 13)		
V max (ml)	Mean	6.9	3.2	4.6	< 0.001 HS
	±SD	0.2	2.8		
V pre A (ml)	Mean	1.9	9.8	5.7	< 0.001 HS
	±SD	.3	2.8		
V min (ml)	Mean	5.2	3.1	7. 1	< 0.001 HS
	±SD	.4	2.7		
Total LAEF %	Mean	5.1	1.6	4.8	< 0.001 HS
	±SD	.1	1.9		
LAVI (ml/m²)	Mean	1.6	1.2	4.4	< 0.001 HS
	±SD	.3	.4		
LA APD (cm)	Mean	.88	.38	4.2	< 0.001 HS
	±SD	.38	.29		
LA TD (cm)	Mean	.90	.35	3.7	< 0.001 HS
	±SD	.35	.41		
LA LD (cm)	Mean	.90	.30	2.68	0.01 S
	±SD	.48	.40		

There was a highly significant (p-value < 0.001) decrease in LA conduit strain % in patients with POAF (-8.9 ± 2.5) when compared with patients of no POAF (-14.5 ± 2.8). Highly significant (p-value < 0.001) decrease in LA contractile strain % in patients with POAF (-11.2 ± 3.8) when compared with patients of no POAF (-15.8 ± 3.5) and highly significant (p-value < 0.001) reduced LA reservoir strain % in patients with POAF (20.2 ± 5.1) when compared with patients of no POAF (30.5 ± 4.7).

Table 6. Comparison of LA strain measurements between POAF patients and those without POAF.

		POAF		T	P-VALUE
		No N =) (37	Yes N =) (13		
LA CONDUIT STRAIN %	Mean	-14.5	-8.9	6.3	< 0.001
	±SD	2.8	2.5		HS
LA CONTRACTILE STRAIN %	Mean	-15.8	-11.2	4.0	< 0.001
	±SD	3.5	3.8		HS
LA RESERVOIR STRAIN %	Mean	30.5	20.2	6.5	< 0.001
	±SD	4.7	5.1		HS

LA conduit Strain % was used to discriminate POAF patients at a cutoff level of <-10.5, with 76.9% sensitivity, 91.8% specificity, 90.4% PPV and 79.9% NPV (AUC = 0.93 & p-value < 0.001). LA contractile Strain % was used to discriminate POAF patients at a cutoff level of < -11.5, with 69.2% sensitivity, 78.3% specificity, 76.1% PPV and 71.7% NPV (AUC = 0.81 & p-value = 0.0007). And LA reservoir Strain % was used to discriminate POAF patients at a cutoff level of < 26.5, with 84.6% sensitivity, 83.7% specificity, 83.8% PPV and 84.4% NPV (AUC = 0.9 & p-value < 0.001).

Table 7. Diagnostic performance of LA strain in discrimination patients with POAF.

	Cut off	*AUC*	*Sensitivity*	*Specificity*	*PPV*	*NPV*	*p-value*
LA Conduit Strain %	< -10.5	0.93	76.9%	91.8%	90.4%	79.9%	< 0.001
LA Contractile Strain %	< -11.5	0.81	69.2%	78.3%	76.1%	71.7%	0.0007
LA Reservoir Strain %	< 26.5	0.9	84.6%	83.7%	83.8%	84.4%	< 0.001

4. Discussion

In our study, the POAF group represented 26% of the total study population. We found that there was a significant increase in age in patients with POAF (65.1 ± 4.94 years) when compared with patients in the no POAF group (56.7 ± 5.86 years). On the other hand, there was no significant relation between POAF and other studied demographic data (sex, BMI, BSA, DM, HTN, and smoking) using an independent sample T-test. The most important findings of our study were that patients in the POAF group had significantly reduced LA strain values.

There was a highly significant (P-value < 0.001) decrease in LA reservoir, conduit, and contractile strain in patients in the POAF group compared with those in the non-POAF group. Using the ROC curve, the best cutoff point for the LA reservoir strain was < 26.5% with 84.6% sensitivity, 83.7% specificity, 83.8% PPV, and 84.4% NPV (AUC = 0.9). The best cutoff point for LA conduit strain was < -10.5%, with 76.9% sensitivity, 91.8% specificity, 90.4% PPV, and 79.9% NPV (AUC = 0.93). The best cutoff point for LA contractile strain was < -11.5% with 69.2% sensitivity, 78.3% specificity, 76.1% PPV, and 71.7% NPV (AUC = 0.81, p-value = 0.0007).

Olga N. Kislitsina et al. published a study similar to ours in September 2022. In September 2022, in the Journal of Thoracic and Cardiovascular Surgery, they studied 211 patients who were planned for isolated CABG surgery and had preoperative LVEF > 50%. They were assessed preoperatively by 2D speckle tracking echocardiography of the LV, RV, and LA and followed up postoperatively by continuous ECG monitoring during their hospital stay. From the study population, 50 patients (24%) developed POAF. The POAF group was older, had a larger LAVI, and had significantly lower LA reservoir and contractile strain values compared with patients in the no POAF group. [13]

Considering that patients with impaired LV systolic function were excluded from our study, our result states that there is no significant disparity among the 2 groups in LV measurements (LVIDd, LVIDs, IVS, and LVPWD) and LVEF assessed by M-Mode and modified Simpson's method using an independent sample T test.

Regarding LA volumetric measurements, patients in the POAF group were found to have a larger LA than those in the no POAF group. Our result states that there is a significant (P-value< 0.001) increase in LA maximal, pre-A, and minimal volumes in the POAF group when compared with the no POAF group.

There was also a significant decrease in the total LA emptying fraction (LAEF) (P-value< 0.001) in the POAF group when compared with the no POAF group. The LA volume index (LAVI) was then found to be significantly (P-value< 0.001) higher in the POAF group (41.2 ± 7.4) compared to the no POAF group (31.6 ± 6.3). The increased LAVI in the POAF group, which is a marker for atrial remodeling due to the chronic increase in LA pressure, indicates more AF and remodeling associated with POAF development.

The results of our study were compatible with those published by Beste Ozben et al. in October 2016 in the Heart, Lung, and Circulation journal, in which 48 patients undergoing CABG (mean age: 61.6 ± 8.9 years, 39 male) were included. All patients were in sinus rhythm during surgery. Patients were followed up postoperatively by continuous ECG monitoring and daily ECG. Both conventional and speckle-tracking echocardiography did preoperative LA functional assessment, and atrial fibrosis was determined by samples taken from the right atrium. Postoperative AF was detected in 13 patients. Female sex and the number of bypassed vessels were significantly higher, and cardiopulmonary bypass time was significantly longer in patients with POAF.

Also, LAVI was significantly higher, and LA reservoir strain was significantly lower in POAF patients, and the percentage of patients with severe AF was higher in the POAF group. [14]

In our study, patients in the POAF group were found to have more impaired diastolic function than those in the no POAF group. We found that there is a highly significant (p-value < 0.001) decrease in peak E\` and an increase in E/E\` and a significant (p-value = 0.001) decrease in peak A\` in patients in the POAF group when compared with patients in the no POAF group. Also, by PW Doppler transmitral flow, patients in the POAF group were found to have significantly lower peak A wave velocity and a higher E: A ratio (P-value = 0.008 and 0.004, respectively) when compared with patients in the no POAF group.

Similarly, In a previous study by Rowlens M. Melduni et al. published in November 2011 in the journal of the American College of Cardiology, diastolic function parameters were studied as a predictor for the development of POAF. In contrast to those with grade I LV diastolic dysfunction (34.6%; 36 of 104), grade II LV diastolic dysfunction (58.2%; 78 of 134), and grade III LV diastolic dysfunction (70.8%; 17 of 24), only 5.1% (4 of 79) of those with normal LV diastolic function exhibited POAF. The frequency of POAF increased sharply with the grade of diastolic dysfunction. Individuals who developed POAF had a significantly higher E/e' ratio (17.3 ± 8.2 vs. 14.4 ± 7.8) and left atrial volume index (42.5 ± 15.0 ml/m2 vs. 34.2 ± 12.8 ml/m2). Nevertheless, patients younger than 60 years with lower grades of LV diastolic dysfunction (grade I) were a lower-risk group (15% risk of developing POAF). Those with an E/e' of 10 had a four-fold higher risk of developing POAF (95% CI: 1.84 to 10.3). [15]

5. *Conclusion*

Speckle-tracking echocardiography may be employed as a reliable, noninvasive tool for assessing atrial mechanical dysfunction in individuals undergoing CABG. This might aid in the detection of patients at high risk for POAF and the avoidance of POAF following CABG.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

References

1. Maesen B, Nijs J, Maessen J, Allessie M, Schotten U. Post-operative atrial fibrillation: a maze of mechanisms. Europace. 2012;14(2):159-174.
2. Villareal RP, Hariharan R, Liu BC, et al. Postoperative atrial fibrillation and mortality after coronary artery bypass surgery. J Am Coll Cardiol. 2004;43(5):742-748.
3. Burashnikov, A.; Antzelevitch, C. Pathophysiology of atrial fibrillation. Cardiac arrhythmias, pacing and sudden death. 2017:15-25.
4. Dobrev D, Aguilar M, Heijman J, Guichard JB, Nattel S. Postoperative atrial fibrillation: mechanisms, manifestations and management. Nat Rev Cardiol. 2019;16(7):417-436.
5. Pagel PS, Kehl F, Gare M, Hettrick DA, Kersten JR, Warltier DC. Mechanical function of the left atrium: new insights based on analysis of pressure-volume relations and Doppler echocardiography. Anesthesiology. 2003;98(4):975-994.

6. Mosquera VX, Bouzas-Mosquera A, González-Barbeito M, et al. Indexed left atrial size predicts all-cause and cardiovascular mortality in patients undergoing aortic valve surgery. J Thorac Cardiovasc Surg. 2017;153(6):1275-1284.e7.
7. Marwick TH. Measurement of strain and strain rate by echocardiography: ready for prime time?. J Am Coll Cardiol. 2006;47(7):1313-1327.
8. Cameli M, Mandoli GE, Loiacono F, Sparla S, Iardino E, Mondillo S. Left atrial strain: A useful index in atrial fibrillation. Int J Cardiol. 2016;220:208-213.
9. Hirose T, Kawasaki M, Tanaka R, et al. Left atrial function assessed by speckle tracking echocardiography as a predictor of new-onset non-valvular atrial fibrillation: results from a prospective study in 580 adults. Eur Heart J Cardiovasc Imaging. 2012;13(3):243-250.
10. Shaikh AY, Maan A, Khan UA, et al. Speckle echocardiographic left atrial strain and stiffness index as predictors of maintenance of sinus rhythm after cardioversion for atrial fibrillation: a prospective study. Cardiovasc Ultrasound. 2012;10:48.
11. Lang RM, Badano LP, Mor-Avi V, 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. J Am Soc Echocardiogr. 2015;28(1):1-39.e14.
12. Voigt JU, Mălăescu GG, Haugaa K, Badano L. How to do LA strain. Eur Heart J Cardiovasc Imaging. 2020;21(7):715-717.
13. Kislitsina ON, Cox JL, Shah SJ, et al. Preoperative left atrial strain abnormalities are associated with the development of postoperative atrial fibrillation following isolated coronary artery bypass surgery. J Thorac Cardiovasc Surg. 2022;164(3):917-924.
14. Ozben B, Akaslan D, Sunbul M, et al. Postoperative Atrial Fibrillation after Coronary Artery Bypass Grafting Surgery: A Two-dimensional Speckle Tracking Echocardiography Study. Heart Lung Circ. 2016;25(10):993-999.
15. Melduni RM, Suri RM, Seward JB, et al. Diastolic dysfunction in patients undergoing cardiac surgery: a pathophysiological mechanism underlying the initiation of new-onset post-operative atrial fibrillation. J Am Coll Cardiol. 2011;58(9):953-961.