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# Evaluation of Left Atrial Function with Two-Dimensional Speckle Tracking Echocardiography in Patients Treated with Electrical Cardioversion and Catheter Ablation for Atrial Fibrillation

## Atriyal Fibrilasyon İçin Elektriksel Kardiyoversiyon ve Kateter Ablasyonu ile Tedavi Edilen Hastalarda Sol Atriyal Fonksiyonun İki Boyutlu Speckle Tracking Ekokardiyografi ile Değerlendirilmesi

**ORIGINAL ARTICLE**
KLİNİK ÇALIŞMA

**ABSTRACT**

**Objective:** The effects of radiofrequency catheter ablation (RFCA) and direct current cardioversion (DCCV) on left atrial (LA) mechanical function and atrial myopathy are not fully understood. In this study, we aimed to compare the changes in myocardial deformation after catheter ablation and electrical cardioversion procedures, in patients with atrial fibrillation (AF).

**Method:** In this study, we retrospectively analyzed echocardiographic parameters of left ventricular and left atrial function and strain measurements with two-dimensional speckle tracking echocardiography (STE), before and after the procedure in patients who underwent RFCA or DCCV for atrial fibrillation.

**Results:** LA reservoir strain (LARS) significantly improved after the procedure in the ablation group (Apical four chamber view LARS 15.1 ± 8.2, 19.6 ± 7.1 P < 0.001, respectively). The Apical four chamber view LARS value also showed a significant improvement after the procedure, compared to the pre-procedure in patients who underwent DCCV (Apical four chamber view LARS 12.2 ± 6.2, 17.3 ± 8.1 P < 0.001, respectively). There was no significant difference in strain change between the groups (p=0.7).

**Conclusion:** In our study, the improvement in the reservoir strain of patients who underwent RFCA was similar to DCCV group. These findings suggest that restoration of sinus rhythm by RFCA, despite the expense of fibrosis in the lesion areas, improves left atrial reservoir function.

**Keywords:** Atrial fibrillation, echocardiography, electrophysiology

**ÖZET**

**Amaç:** Radyofrekans kateter ablasyonu (RFKA) ve doğru akım kardiyoversiyon (DCCV) sol atriyal (LA) mekanik fonksiyon ve atriyal miyopati üzerindeki etkileri tam olarak anlaşılamamıştır. Bu çalışmada, atriyal fibrilasyonlu (AF) hastalarda kateter ablasyonu ve elektriksel kardiyoversiyon prosedürlerinden sonra miyokardiyal deformasyondaki değişiklikleri karşılaştırmayı amaçladık.

**Yöntem:** Bu çalışmada, atriyal fibrilasyon nedeniyle RFCA veya DCCV uygulanan hastalarda işlem öncesi ve sonrası sol ventrikül ve sol atriyal fonksiyon ekokardiyografik parametrelerini ve iki boyutlu benek takibi ekokardiyografi (BTE) ile strain ölçümlerini retrospektif olarak analiz ettik.

**Bulgular:** Ablasyon grubunda işlem öncesine kıyasla işlem sonrasında LA rezervuar strain (LARS) anlamlı olarak arttı (4 odacık LARS sırasıyla 15.1±8.2, 19.6±7.1 p<0.001). DCCV uygulanan hastalarda da 4 odacıklı LARS değeri işlem öncesine kıyasla işlem sonrasında anlamlı bir iyileşme gösterdi (sırasıyla 4 odacıklı LARS 12,4±6,2, 17,3±8,1 p<0,001). Gruplar arasında strain değişikliği açısından anlamlı bir fark yoktu (p=0.7).

**Sonuç:** Çalışmamızda, RFKA uygulanan hastaların rezervuar gerinimindeki iyileşme DCCV grubuna benzerdi. Bu bulgular, lezyon alanlarında fibrozis pahasına da olsa, RFKA ile sinüs ritminin restorasyonunun sol atriyal rezervuar fonksiyonunu iyileştirdiğini göstermektedir.

**Anahtar Kelimeler:** Atriyal fibrilasyon, ekokardiyografi, elektrofizyoloji

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Atrial cardiomyopathy is a combination of structural, electrical or functional changes in the atria leading to clinical effects and includes inflammatory and prothrombotic remodelling of the atria, neurohormonal activation and fibrosis of myocardial tissue.[1] Atrial fibrillation (AF) itself causes atrial myopathy, which facilitates the long-term persistence of arrhythmia in the atrial myocardium, while atrial myopathy may contribute to the onset of AF.[2] The latest research indicates that treatments targeting the mechanism responsible for atrial myopathy may slow down the process of left atrial remodelling and facilitate reverse atrial remodeling.[3] The 2024 European Society of Cardiology (ESC) Guidelines for the management of atrial fibrillation, recommend rhythm control strategy intending to improve AF-related symptoms and reduce morbidity and mortality in selected patient groups.[1,4–6]

Although there is evidence that radiofrequency catheter ablation (RFCA) improves left atrial (LA) function in patients with atrial fibrillation (AF), the procedure may also cause atrial damage by radiofrequency (RF) energy. While RFCA may enhance LA function by maintaining sinus rhythm, RFCA may also result in iatrogenic myocardial damage, leading to new scar formation and LA dysfunction.[7–9] There is also data in favour of improvement in atrial function and reverse remodelling after electrical cardioversion.[10]

So far, no study has compared changes in left atrial function after catheter ablation and electrical cardioversion. The primary aim of our study was to compare changes in myocardial deformation after radiofrequency catheter ablation and electrical cardioversion in patients with atrial fibrillation, as well as to determine how and to what extent these procedures affect the atrial reservoir function.

## ABBREVIATIONS

| | |
|---|---|
| A2C | Apical two chamber |
| A4C | Apical four chamber |
| AF | Atrial fibrillation |
| AFCARD | Acute kidney injury following cardioversion for atrial fibrillation |
| AFI | Automated function imaging |
| DCCV | Direct current cardioversion |
| ESC | European Society of Cardiology |
| LA | Left atrium |
| LAD | Left atrial diameter |
| LARS | Left atrial reservoir strain |
| LGE | Late gadolinium enhancement |
| LVEF | Left ventricular ejection fraction |
| MRI | Magnetic resonance imaging |
| RF | Radiofrequency |
| RFCA | Radiofrequency catheter ablation |
| ROI | Region of interest |
| SPAP | Systolic pulmonary artery pressure |
| STE | Speckle tracking echocardiography |
| TTE | Transthoracic echocardiogram |

## Materials and Methods

This cross-sectional study was conducted in accordance with the Declaration of Helsinki and received approval from Ankara University Human Research Ethics Committee (Approval Number: İ10-608-22, Date: 10.11.2022). Artificial intelligence assisted technologies were not used in the production of this study.

### Study Design and Patient Selection

In this study, we reviewed 660 patients who underwent catheter ablation or electrical cardioversion for atrial fibrillation at our center. Patients with appropriate images and measurements for strain by two-dimensional speckle tracking echocardiography in pre-procedural and post-procedural echocardiographic evaluations, were retrospectively screened. Patients with a left ventricular ejection fraction (LVEF) < 50%, a history of mechanical mitral valve replacement, mitral stenosis and above moderate mitral regurgitation, were excluded. In order to clearly evaluate the effect of sinus rhythm restoration, patients with AF recurrence within three months were excluded. Figure 1 shows the inclusion and exclusion flowchart for the study.

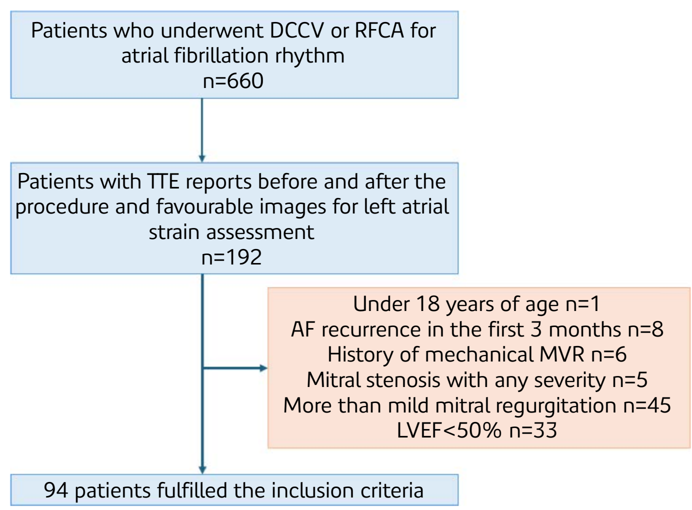


**Figure 1. Patient inclusion flowchart for the study.**

**AF, Atrial fibrillation; DCCV, Direct current cardioversion; LVEF, Left ventricular ejection fraction; RFCA, Radiofrequency catheter ablation, TTE, Transthoracic echocardiogram.**

### Echocardiographic Studies

Echocardiographic studies of the patients were obtained in the echocardiography laboratory of our hospital in accordance with the guidelines and recorded in the EchoPac system. The transthoracic echocardiogram (TTE) reports of the patients were retrospectively reviewed. The strain analyses were performed by a single cardiologist trained in advanced imaging and strain analysis. The cardiologist performing the follow-up speckle-tracking echocardiograms was unaware of the specific procedure applied to each patient. The GE Vivid E9 (GE Healthcare) was used as the echocardiography device and 2D speckle-tracking echocardiography measurements of LA strain and strain rate, were obtained according to the standardized measurement recommendations of the 2018 EACVI/ASE consensus document. If the LA image quality was not suitable for measurements or if tracking quality could not be improved by adjusting the region of interest (ROI), the image was not used to measure LA strain. Zero reference was defined as end-diastole. The analysis was performed using the Automated Function Imaging (AFI) method.

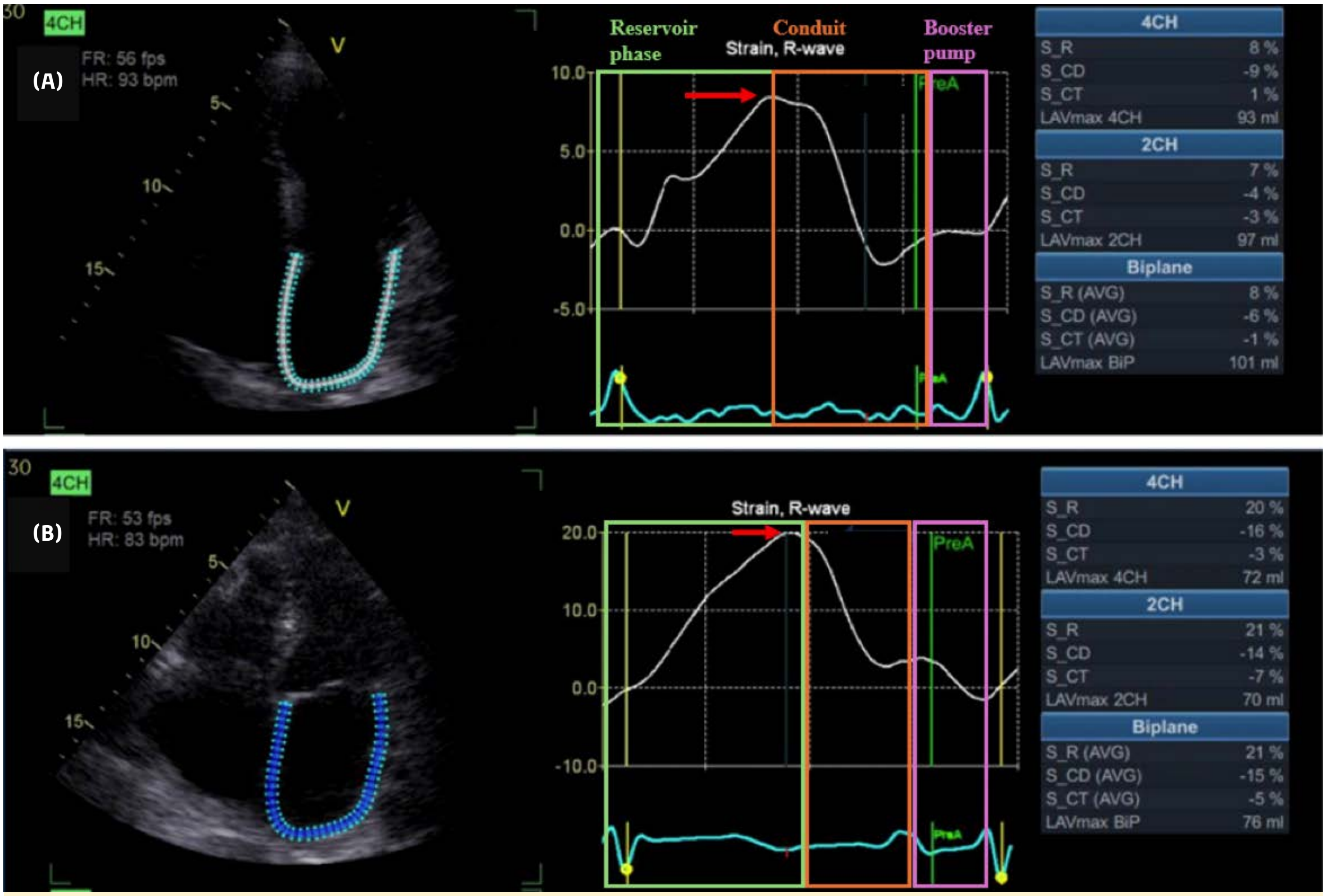


**Figure 2. Pre-procedure (A) and post-procedure (B) measurements of LA reservoir strain by speckle tracking in a patient who underwent RFCA. Red arrows indicate A4C LARS values.**

The LA reservoir strain (LARS) is calculated as LARS = peak systolic strain – the strain value at the end-diastole. LA diameter was measured from the parasternal long axis view. LA strain analyses were performed with Automated Function Imaging (AFI) software. LA volumes at end-systole were determined from apical two chamber view (A2C) and apical four chamber (A4C) view images, using the biplane area length method. Figure 2 shows LA strain measurements before and after the procedure in a patient evaluated with the speckle tracking echocardiography (STE). In patients with AF, an average of five beats was obtained in all measurements.

**Clinical follow-up and Data Collection**

Information on the demographic and clinical characteristics of all patients was obtained from the follow-up files and the hospital system. All patients underwent the clinical follow-up procedures that had been predetermined: they all underwent TTE before and three months after the procedure. Routine annual follow-up was planned unless the clinical condition required more frequent visits and the echocardiographic images of the patients were retrospectively analyzed.

**Ablation Procedure**

In our clinic, a mapping catheter and an irrigated contact force sensing catheter are used for mapping and radiofrequency (RF) ablation. Navigation of the catheters is based on fluoroscopy and an electro-anatomical system (CARTO 3, Biosense Webster, Irwindale, CA, USA). The ipsilateral pulmonary veins are jointly isolated, and the maximum intersection distance is set to 6 mm. The endpoint of the procedure is the isolation of all pulmonary veins. Posterior wall isolation and scar homogenization or other procedures in addition to PVI were performed on an individual patient basis, at the initiative of the operator.

**Statistical Analysis**

Statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS) Statistics 23.0 software (IBM Corp., released in 2012, Armonk, NY, USA). Categorical variables were expressed as percentages and numerical variables were expressed as arithmetic mean ± standard deviation. In addition to descriptive statistical methods (mean, standard deviation), independent t-tests were used in the comparison of paired groups and the Yates correction was used in the comparison of qualitative data. The Fisher Exact test was used in case of the smallest theoretical frequency < 5. The paired t-test was used for the comparison of dependent variables. The results were considered statistically significant if the P value was < 0.05.

**Table 1. Comparison of demographic and clinical characteristics of patients treated with DCCV and RFCA**

| Variables | DCCV group (n = 45) | RFCA group (n = 49) | P |
|---|---|---|---|
| Age | 65 ± 13 | 64.6 ± 12.1 | 0.9 |
| Male sex, % (n) | 49 (22) | 49(24) | 1 |
| BSA | 1.91 ± 0.18 | 1.92 ± 0.20 | 0.85 |
| CHA2DS2VASc score | 3.13 ± 1.6 | 2.9 ± 1.8 | 0.6 |
| Persistent AF, % (n) | %83.2 (37) | %69.4 (34) | 0.35 |
| Paroxysmal AF, % (n) | %17.8 (8) | %30.6 (15) | 0.30 |
| Risk factors | | | |
| Hypertension, % (n) | %80 (36) | %70 (34) | 0.34 |
| Dyslipidemia, % (n) | %47 (21) | %43 (21) | 0.84 |
| Diabetes mellitus, % (n) | %27 (12) | %33 (16) | 0.66 |
| Smoking, % (n) | %24 (11) | %51 (25) | 0.01 |
| Stroke, %(n) | %2 (1) | %6 (3) | 0.62 |
| ASCVD, % (n) | %22 (10) | %31 (15) | 0.48 |
| Drugs | | | |
| ACEI, % (n) | %33 (15) | %27 (13) | 0.5 |
| ARB, % (n) | %40 (18) | %37 (18) | 0.8 |
| BB, % (n) | %75 (34) | %69 (34) | 0.8 |
| CCB, % (n) | %22 (10) | %14 (7) | 0.42 |
| Digitals, % (n) | %29 (13) | %8 (4) | 0.01 |
| Diuretic, % (n) | %40 (18) | %18 (9) | 0.02 |
| Statins, % (n) | %38 (17) | %39 (19) | 1 |

AF, Atrial fibrillation; ACE, Angiotensin-converting enzyme; ARB, Angiotensin receptor blocker; ASCVD, Atherosclerotic cardiovascular disease; BB, Beta-blocker; BSI, Body surface area; CCB, Calcium channel blocker; DCCV, Direct current cardioversion.

## Results

### Patient Characteristics

Our study was performed with 45 patients who underwent electrical cardioversion (DCCV) and 49 patients who underwent radiofrequency catheter ablation (RFCA). The rate of smoking was significantly higher in patients who underwent RFCA. The groups were similar in terms of age, gender, presence of atherosclerotic heart disease, hypertension, dyslipidemia and diabetes. There was no significant difference in the type of atrial fibrillation between the DCCV and RFCA groups. All patients in the study were in sinus rhythm at three months and patients with AF recurrence were not included in the study. AF recurrence is a critical outcome that affects LA function and remodelling, and patients with AF recurrence were not included in our study to ensure homogeneity of the groups and because the LARS value may be influenced by the current rhythm.

Detailed information about the descriptive characteristics of the patients is presented in Table 1.

When pre-procedural echocardiographic parameters were evaluated, the LA area was 22.7 ± 4.8 mm$^2$ in the DCCV group and 21.8 ± 5.7 mm in the RFCA group and no significant difference was found (P = 0.54). LAVI was 32.7 ± 11.01 (ml/m$^2$) in the DCCV group and 31.9 ± 9.3 (ml/m$^2$) in the RFCA group and no difference was found between the groups (P = 0.71). When the pre-procedure two-dimensional STE measurements of the patients were compared, no statistically significant difference was observed in strain parameters. A4C LARS was 12.43 ± 6.19% in DCCV group and 15.1 ± 8.2% in RFCA group (P = 0.81). A4C LARS values were found to be higher in the RFA group before the procedure, but no statistically significant difference was found. Pre-procedural echocardiographic parameters are shown in Table 2.

**Table 2. Comparison of pre-procedural echocardiographic parameters of patients with DCCV and RFCA**

| Echocardiographic parameters | DCCV group (n = 45) | RFCA group (n = 49) | P |
|---|---|---|---|
| LAD (mm) | 46.18 ± 5.9 | 44.7 ± 8.2 | 0.31 |
| LA area (mm$^2$) | 22.7 ± 4.8 | 21.8 ± 5.7 | 0.54 |
| LAVI (ml/m$^2$) | 32.7 ± 11.01 | 31.9 ± 9.3 | 0.71 |
| LAVmax (ml) | 62.6 ± 20.4 | 62 ± 20.01 | 0.87 |
| LVEDD (mm) | 50.2 ± 5.96 | 49.3 ± 6.07 | 0.47 |
| LVESD (mm) | 33.8 ± 6.1 | 34.02 ± 7.5 | 0.86 |
| LVEF (%) | 58.2 ± 6.9 | 59.8 ± 6.3 | 0.26 |
| TAPSE (cm) | 2.27 ± 1.8 | 2.02 ± 0.33 | 0.38 |
| SPAP (mmHg) | 37.2 ± 12.8 | 38.2 ± 10.4 | 0.41 |
| TRvmax (m/sn) | 3.14 ± 3.1 | 2.6 ± 0.49 | 0.23 |
| Mitral E (m/sn) | 0.87 ± 0.25 | 0.78 ± 0.23 | 0.07 |
| Mitral E/e' mean | 10.2 ± 3.8 | 9.4 ± 2.85 | 0.34 |
| A4C LARS (%) | 12.4 ± 6.19 | 15.1 ± 8.2 | 0.81 |
| Persistent AF | 11.5 ± 5.3 | 12.2 ± 6.8 | 0.19 |
| Paroxysmal AF | 16.3 ± 8.4 | 21.5 ± 7.3 | 0.125 |

DCCV, Direct current cardioversion; LA, Left atrial; LAD, Left atrium diameter; LARS, Left atrial strain reservoir phase; LAVI, Left atrium volume index; LAVmax, Left atrium maximum volume; LVEDD, Left ventricular end-diastolic diameter; LVEF, Left ventricular ejection fraction; LVESD, Left ventricular end-systolic diameter; RFCA, Radiofrequency catheter ablation; SPAP, Systolic pulmonary artery pressure; TAPSE, Tricuspid annular plane systolic motion.

When the pre-procedural and three-month post-procedural control echocardiographic findings of all patients were compared, the post-procedural decrease in left atrium diameter (LAD) was found to be statistically significant. The mean values of SPAP and Mitral E/e' were significantly lower after the procedure. A4C LARS was found to be significantly increased after the procedure. When the echocardiographic parameters of the RFCA group were evaluated before and after the procedure, it was found that although there was a decrease in LAVI, it did not reach statistical significance, but there was a statistically significant decrease in LAVmax and SPAP. A4C LARS was found to be significantly higher after the procedure (P < 0.001). The results demonstrated no notable alteration in LAVI, LAVmax and LA area, in patients who underwent electrical cardioversion. The mean mitral E/e' value in mitral flow samples of the patients was significantly lower after the procedure. Furthermore, A4C LARS was found to be significantly higher after the procedure (P < 0.001). Details regarding the comparison of echocardiographic parameters of all patients and groups before and after the procedure are provided in

**Table 3. Comparison of echocardiographic parameters of patients before and after the procedure**

| | All patients (n = 94) | | | RFCA group | | | DCCV group | | |
|---|---|---|---|---|---|---|---|---|---|
| | Preprocedural measurements | Postprocedural measurements | P | Preprocedural measurements | Postprocedural measurements | P | Preprocedural measurements | Postprocedural measurements | P |
| LAD (mm) | 45.4 ± 7.3 | 43 ± 10 | 0.03 | 44.73 ± 8.3 | 41.1 ± 12.2 | 0.08 | 46.3 ± 6 | 45.1 ± 6.7 | 0.02 |
| LA area ($mm^2$) | 23.8 ± 14.5 | 21.6 ± 5.4 | 0.14 | 21,8 ± 5,7 | 20.8 ± 5.4 | 0.2 | 22.8 ± 4.8 | 22.4 ± 5.3 | 0.6 |
| LAVI ($ml/m^2$) | 32.4 ± 10.2 | 31.4 ± 10.2 | 0.12 | 32.1 ± 9.4 | 30.4 ± 9.5 | 0.07 | 32.7 ± 11.1 | 32.5 ± 10.9 | 0.8 |
| LAVmax (ml) | 62.4 ± 20.3 | 60.4 ± 20.2 | 0.1 | 62.6 ± 20.2 | 58.7 ± 20.1 | 0.03 | 62.6 ± 20.6 | 62.3 ± 20.6 | 0.9 |
| LVEDD (mm) | 49.8 ± 6.1 | 49.2 ± 7.7 | 0.4 | 49.3 ± 6.1 | 48.3 ± 8.8 | 0.4 | 50.3 ± 6 | 50.2 ± 6.1 | 0.9 |
| LVESD (mm) | 33.9 ± 6.9 | 33.7 ± 7.6 | 0.85 | 33.9 ± 7.5 | 33.3 ± 7.8 | 0.6 | 33.8 ± 6.2 | 34.2 ± 7.5 | 0.6 |
| LVEF (%) | 58.7 ± 6.6 | 59,29 ± 5,93 | 0.44 | 59.3 ± 6.1 | 60.2 ± 5.2 | 0.14 | 57.8 ± 7 | 58,7 ± 5.22 | 0.4 |
| TAPSE (cm) | 2.2 ± 1.3 | 2.04 ± 0.33 | 0.5 | 2.0 ± 0.3 | 2.1 ± 0.3 | 0.2 | 2.3 ± 1.9 | 2.0 ± 0.4 | 0.4 |
| SPAP (mmHg) | 2.88 ± 2.3 | 2.6 ± 0.47 | 0.23 | 2.6 ± 0.5 | 2.5 ± 0.5 | 0.3 | 3.2 ± 3.3 | 2.6 ± 0.5 | 0.3 |
| TRvmax (m/sn) | 36.4 ± 12 | 33.6 ± 10.2 | 0.007 | 35.2 ± 10.7 | 31.8 ± 10 | 0.03 | 37.8 ± 13.3 | 36 ± 10 | 0.2 |
| Mitral E (m/sn) | 0.80 ± 0.23 | 0.79 ± 0.22 | 0.24 | 0.8 ± 0.21 | 0.8 ± 0.2 | 0.8 | 0.84 ± 0.24 | 0.81 ± 0.22 | 0.1 |
| Mitral E/e' mean | 10.2 ± 3.3 | 9.3 ± 3.24 | 0.01 | 9.7 ± 2.5 | 8.8 ± 2.8 | 0.08 | 10.7 ± 3.9 | 9.6 ± 3.7 | 0.002 |
| A4C LARS (%) | 13.7 ± 7.29 | 18.5 ± 7.7 | <0.001 | 15.1 ± 8.2 | 19.6 ± 7.3 | <0.001 | 12.4 ± 5.8 | 17.3 ± 8.1 | <0.001 |

A4C, Apical four chamber; DCCV, Direct current cardioversion; LAD, Left atrium diameter; LARS, Left atrial strain reservoir phase; LAVI, Left atrium volume index; LAVmax, Left atrium maximum volume; LVEDD, Left ventricular end-diastolic diameter; LVEF, Left ventricular ejection fraction; LVESD, Left ventricular end-systolic diameter; RFCA, Radiofrequency catheter ablation; SPAP, Systolic pulmonary artery pressure; TAPSE, Tricuspid annular plane systolic motion.

**Table 4. Pre and postprocedural A4C LARS values of patients according to atrial fibrillation types**

| | Persistent AF | Paroxysmal AF | P |
|---|---|---|---|
| Preprocedural A4C LARS | 11.8 ± 6.2 | 19.7 ± 7.9 | <0.001 |
| DCCV | 11.5 ± 5.3 | 16.3 ± 8.4 | 0.001 |
| RFCA | 12.2 ± 6.8 | 21.5 ± 7.3 | <0.001 |
| Postprocedural A4C LARS | 16.8 ± 6.0 | 23.6 ± 7.4 | <0.001 |
| DCCV | 16.0 ± 7.8 | 22.7 ± 7.0 | 0.03 |
| RFCA | 12.2 ± 6.8 | 24.1 ± 5.9 | <0.003 |

AF, Atrial fibrillation; DCCV, electrical cardioversion; LARS, Left atrial strain reservoir phase; RFCA, radiofrequency catheter ablation.

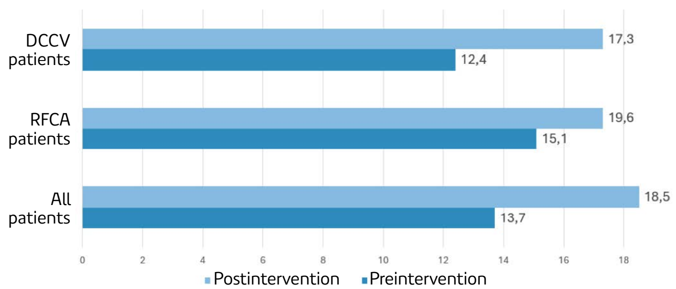


**Figure 3. Change in the A4C LARS value of the groups before and after the procedure..**

**DCCV, Direct current cardioversion; RFCA, Radiofrequency catheter ablation.**

Table 3. Pre- and post-procedure A4C LARS values of all patients, RFCA group and DCCV group are summarized in Figure 3.

Table 4 shows the A4C LARS values according to the atrial fibrillation subgroups of patients and the procedure performed. The LARS value of patients with persistent AF was lower than that of patients with paroxysmal AF in both groups before and after the procedure. However, both procedures were associated with an improvement in reservoir function in both the paroxysmal and persistent AF patient subgroups.

The A4C LARS in the DCCV group was 12.4 ± 6.2% and 17.3 ± 8.1% before and after the procedure, respectively, and in the RFCA group it was 15.1 ± 8.2% and 19.6 ± 7.1%, respectively, and no significant difference was found between the groups in terms of LARS increase (P = 0.4). Similarly, the change in other echocardiographic findings was similar between the two groups. Detailed information about the evaluation of the changes in echocardiographic parameters in patients who underwent DCCV and RFCA is given in Table 5.

One of the patients presented with dyspnea and pulmonary edema within 48 hours of AF ablation. Preprocedural echocardiography showed moderate mitral regurgitation, moderate to severe tricuspid regurgitation and stage 2 diastolic dysfunction. The A4C LARS were 8% pre-procedure and 10% post-procedure. The patient's left atrial mapping showed diffuse low-voltage areas and posterior wall isolation was performed in addition to PVI. We suspected that the patient had developed stiff atrium syndrome. One of our patients who underwent cardioversion developed acute kidney injury following cardioversion for atrial fibrillation (AFCARD)

**Table 5. Comparison of the change in baseline and 3rd month measurements of patients**

| Groups and variables | | Preprocedural measurements | Postprocedural measurements | P |
|---|---|---|---|---|
| DCCV | LAD (mm) | 46.3 ± 6.0 | 45.1 ± 6.7 | 0.33 |
| RFCA | | 44.6 ± 8.2 | 41.1 ± 12.1 | |
| DCCV | LA area ($mm^2$) | 22.8 ± 4.8 | 22.4 ± 5.3 | 0.3 |
| RFCA | | 21,8 ± 5,7 | 20.8 ± 5.4 | |
| DCCV | LAVI ($ml/m^2$) | 32.7 ± 11.1 | 32.5 ± 10.9 | 0.7 |
| RFCA | | 32 ± 9.3 | 30.4 ± 9.5 | |
| DCCV | LAVmax ($ml/m^2$) | 62.6 ± 20.6 | 62.3 ± 20.6 | 0.6 |
| RFCA | | 62 ± 20 | 58.6 ± 20 | |
| DCCV | LVEDD (mm) | 50.3 ± 6 | 50.2 ± 6.12 | 0.62 |
| RFCA | | 49.3 ± 6.06 | 48.3 ± 8.8 | |
| DCCV | LVESD (mm) | 33.8 ± 6.2 | 34.2 ± 7.5 | 0.6 |
| RFCA | | 34 ± 7.5 | 33.3 ± 7.8 | |
| DCCV | LVEF (%) | 57.8 ± 7 | 72 ± 84.6 | 0.3 |
| RFCA | | 59.3 ± 6.2 | 60.3 ± 5.2 | |
| DCCV | TAPSE (cm) | 2.3 ± 1.9 | 2.01 ± 0.4 | 0.3 |
| RFCA | | 2.0 ± 0.33 | 2.1 ± 0.3 | |
| DCCV | TRvmax (m/sn) | 3.2 ± 3.3 | 2.6 ± 0.5 | 0.7 |
| RFCA | | 2.6 ± 0.5 | 2.5 ± 0.5 | |
| DCCV | SPAP (mmHg) | 37.8 ± 13.3 | 36.2 ± 10 | 0.58 |
| RFCA | | 35.2 ± 10.7 | 31.8 ± 10 | |
| DCCV | Mitral E (m/sn) | 0.84 ± 0.24 | 0.80 ± 0.22 | 0.32 |
| RFCA | | 0.8 ± 0.21 | 0.8 ± 0.23 | |
| DCCV | Mitral E/e' mean | 10.7 ± 3.8 | 9.6 ± 3.7 | 0.9 |
| RFCA | | 9.7 ± 2.5 | 8.8 ± 3 | |
| DCCV | A4C LARS (%) | 12.4 ± 6.2 | 17.3 ± 8.1 | 0.4 |
| RFCA | | 15.1 ± 8.2 | 19.6 ± 7.1 | |

A4C, Apical four chamber; DCCV, Direct current cardioversion, LA, Left atrial; LAD, Left atrium diameter; LAVI, Left atrium volume index; LAVmax, Left atrium maximum volume; LARS, Left atrial strain reservoir phase; LVEDD, Left ventricular end-diastolic diameter; LVESD, Left ventricular end-systolic diameter; LVEF, Left ventricular ejection fraction.

syndrome. The 82-year-old male patient was in New York Heart Association (NYHA) class 2 before the procedure. He had a known diagnosis of heart failure with preserved EF. Preprocedural echocardiogram showed grade 2 diastolic dysfunction, dilated left atrium, moderate mitral regurgitation, moderate tricuspid regurgitation (thought to be functional), dilated IVC and elevated pulmonary artery systolic pressure (SPAP: 55 mmHg). On the day after cardioversion, the patient had elevated serum creatinine, dyspnea and a nasal O2 requirement of 4 l/min. The patient's creatinine level was 1.61 mg/dL pre-procedure and increased to 3.10 mg/dL post-procedure. In the ablation group, a femoral hematoma was noted in four patients and a pseudoaneurysm requiring surgical repair in one patient.

## Discussion

In our study, we observed improvement in left atrial reservoir function in patients with atrial fibrillation who achieved sinus rhythm with RFCA and DCCV. Our study contributes to the literature in this context by suggesting that rhythm control strategies may promote atrial reverse remodelling.

The reservoir, conduit and booster pump functions of the LA can be quantitatively assessed by speckle tracking echocardiography of the left atrium. LA strain is sensitive to subtle changes and can detect changes in LA myocardial function before macroscopic changes are observed.[11,12] Recent studies have shown that LA reservoir strain is a strong and sensitive marker for the development of AF and that a decrease in LA strain is a marker of fibrous atrium with reduced contractile capacity and decreased compliance.[13–15] In our study, we used left atrial reservoir strain assessment as a marker of changes in left atrial mechanical function, after sinus rhythm restoration by catheter ablation and electrical cardioversion.

The A4C LARS values of patients who underwent DCCV and RFCA increased three months after the procedure compared to the pre-procedure values. The increase in left atrial reservoir strain observed in this study may be associated with atrial reverse remodelling. In a study that examined biatrial remodelling in patients with AF who had undergone successful electrical cardioversion, a notable reduction in LA 3D volumes and a substantial enhancement in left atrial strain were observed six months after the procedure. They published that cardioversion has potential favourable effects on LA functional remodeling.[10]

The effects of catheter ablation on left atrial mechanical function remain unclear. One study demonstrated a decline in left atrial function immediately following catheter ablation.[16] In some previous studies, thermal methods such as RF were found to cause coagulation necrosis, including edema, intramural hemorrhage and microvascular damage. In the chronic phase, these lesions are thought to transform into areas of reparative fibrosis, leading to increased scar tissue and decreased compliance after ablation. Cochet et al.[17] published a study supporting an increase in post-procedural scar burden and a decrease in reservoir function in patients evaluated with cardiac magnetic resonance imaging (MRI). Nakatani et al.[18] compared pulsed field ablation and catheter ablation and found that acute late gadolinium enhancement (LGE) involvement evaluated by cardiac MR improved in patients undergoing pulsed field ablation, but acute LGE involvement persisted in most patients undergoing thermal RF ablation. Another recent study performed cardiac MRI and echocardiographic LA strain assessment and found that the decrease in LA mechanical function after ablation recovered approximately ten days after ablation.[19] In our study, we aimed to compare whether there was a difference in the change in atrial function in patients who underwent RFCA or DCCV. The recovery of reservoir strain in the RFCA group was similar to the cardioversion group. There are concerns that there may be a decrease in diastolic function and/or compliance of the LA after radiofrequency ablation of AF. Stiff LA syndrome after catheter ablation for AF is a potential complication of the procedure. Loss of cardiomyocytes after catheter ablation has been shown to cause replacement fibrosis affecting up to 30-35% of the LA wall. While this may be moderate and well tolerated in patients with paroxysmal AF and a healthy atrium, patients with a fibrotic, reduced-compliance left atrium, especially those with HFpEF, are at higher risk of stiff LA syndrome.[20–22]

### Limitations of the Study

Our study was retrospective and included patients who had echocardiographic measurements three months after the procedure and fulfilled the eligibility criteria for evaluation by speckle-tracking echocardiography. Patients with insufficient image quality to measure LA strain were excluded from the study, which may lead to selection bias. The number of patients who underwent catheter ablation or cardioversion for atrial fibrillation in our clinic is much higher than the study group. The effect of RFCA and DCCV on LA structure and function needs to be confirmed in larger, randomized controlled trials. Another important limitation is that the most reliable LARS measurements can be performed under sinus rhythm, however all of our cardioversion patients and the majority of patients in the ablation group were in AF rhythm, before the procedure. It is difficult to determine whether the changes in left atrial reservoir stroke three months after the procedure are due to changes in cardiac rhythm or to the actual remodelling process. Follow-up at three months is probably too short to fully assess cardiac remodelling.

## Conclusion

The present study demonstrates that the improvement in reservoir strain observed in patients who underwent radiofrequency catheter ablation, is comparable to that observed in the electrical cardioversion group. These findings suggest that restoration of sinus rhythm leads to an improvement in left atrial reservoir function despite fibrosis in the lesion areas, in patients who have undergone RFCA.

**Ethics Committee Approval:** Ethics committee approval was obtained from Ankara University Human Research Ethics Committee (Approval Number: İ10-608-22, Date: 10.11.2022).

**Informed Consent:** Written informed consent was not required due to the retrospective nature of the study.

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