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# Effectiveness of transoesophageal echocardiography guided direct current cardioversion in patients with atrial fibrillation

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**Abstract**
**Background:** Atrial fibrillation (AF) is common in the community and its incidence is rising. Attempting to restore sinus rhythm is mandatory to avoid the wide range of complications. Unfortunately, pharmacological cardioversion generally has poor outcome. Electrical cardioversion is often more effective in restoring sinus rhythm.
**Aim of the study:** Assessment of feasibility, safety and effectiveness of direct current cardioversion (DCCV) that is guided by transoesophageal echocardiography (TEE) in restoring sinus rhythm in patients with AF, to assess the rate of recurrence of AF in the intermediate term, and to determine the factors that predict failure to restore sinus rhythm or recurrence of AF in the intermediate term.
**Patients and methods:** All patients with persistent AF undergoing TEE-guided DCCV were included in this prospective study. After relevant clinical workup, a comprehensive transthoracic echocardiographic assessment preceded transesophageal echocardiography, which was primarily performed to rule out left atrial appendage thrombus, and also to perform a complete study. After optimization of treatment, all eligible patients received DC cardioversion. In patients who converted to sinus rhythm, follow-up was performed to assess recurrence and any change in left ventricle function or clinical status.
**Results:** 57 patients with AF were included, their ages ranged from (37 to 80 years), there were 31 males and 26 females. (13) were diabetics, (31) hypertensives. In (23) there was left ventricle dysfunction. Of the 57 patients studied, DC cardioversion could immediately restore sinus rhythm in 53 patients (immediate success rate of 93%). At completion of the study, 46 remained in sinus rhythm and 7 more patient had recurrence of AF (19%), amounting to an intermediate-term success rate of (80.7%). There was no statistical difference in age, body mass index, gender, history of alcohol intake, and smoking history between patients attaining sinus rhythm and atrial fibrillation persistence/recurrence. Longer duration of AF was weakly associated with higher risk of AF recurrence (104 vs. 23.5 weeks) but is was not statistically significant (p=0.067), left atrial size had fair ability to predict atrial fibrillation recurrence (AUC=0.766, p = 0.004) with optimal cut point of >41 mm, having 100% sensitivity, 58.7% specificity. Structural heart disease was present in (7) patients with successful DCCV and (5) patients with failure/recurrence.
**Conclusion**: DC cardioversion for selected group of patients with persistent AF is a safe and highly effective method of rhythm conversion. Left atrial size, longer duration of AF and structural heart disease were fair predictors of failure/recurrence.

**Keywords:** Atrial fibrillation, direct current cardioversion, transesophageal echocardiography, sinus rhythm restoration, recurrence predictors

## Introduction
Atrial fibrillation (AF) stands as a pervasive and increasingly prevalent cardiac arrhythmia globally, characterized by irregular electrical activity in the atria that results in an erratic ventricular response. This condition not only severely compromises the quality of life for affected individuals but also significantly increases the risks of stroke, mortality, and imposes substantial economic burdens on healthcare systems worldwide. In the United States alone, the annual healthcare expenditures related to AF are estimated at a staggering $6.65 billion (Wodchis *et al*., 2012) [7]. With an aging population and escalating prevalence of cardiovascular risk factors such as hypertension, diabetes, and obesity, the burden of AF is projected to escalate dramatically.

Epidemiological projections suggest that the prevalence of AF may nearly triple by the year 2050, underscoring the urgent need for effective prevention and management strategies (Miyasaka *et al*., 2006; January *et al*., 2014) [4, 3].

AF manifests in various forms, including paroxysmal (intermittent) and persistent (continuous), with symptoms ranging from palpitations, fatigue, and dyspnea to severe complications such as thromboembolic events. The irregular heart rhythm in AF predisposes individuals to the formation of blood clots in the atria, particularly in the left atrial appendage, which can embolize to the brain, causing devastating ischemic strokes. AF is implicated in approximately 15–20% of ischemic strokes in nonrheumatic patients, highlighting its critical role as a significant contributor to cerebrovascular morbidity and mortality (Steinberg *et al*., 2015) [6].

The clinical course of AF is complex and often influenced by various cardiovascular comorbidities, including heart failure, valvular heart disease, coronary artery disease, and structural heart abnormalities, as well as non-cardiovascular factors such as thyroid disorders and chronic lung disease (Guha & McDonagh, 2013; Steinberg *et al*., 2015) [2, 6]. Management of AF is multifaceted, involving strategies aimed at rhythm control, rate control, and prevention of thromboembolic events through anticoagulation therapy.

Despite significant advances in treatment modalities, considerable challenges persist in the optimal management of AF due to its heterogeneous presentation, variable response to therapies, and the occurrence of asymptomatic or subclinical forms. Emerging technologies and evolving clinical guidelines continue to shape the landscape of AF management, emphasizing personalized approaches and targeted interventions to improve outcomes and quality of life for patients.

This comprehensive review aims to delve into the profound clinical significance of AF, elucidate its intricate association with various cardiovascular and non-cardiovascular conditions, discuss current and emerging management strategies (Fetsch *et al*., 2004; Savelieva & Camm, 2000; Steinberg *et al*., 2015) [1, 5, 6], and identify critical areas for future research aimed at advancing our understanding and treatment of this prevalent and debilitating cardiac arrhythmia.

## Methodology

### Study Design, Settings, and Duration

This was a meticulously designed, prospective, single-center study conducted at Al-Zahraa Teaching Hospital, covering a period from September 10, 2019, to March 1, 2022. The study was aimed at evaluating the efficacy and safety of direct current cardioversion (DCCV) in patients diagnosed with atrial fibrillation (AF). Data collection was executed through structured interviews with patients and their relatives, ensuring a comprehensive accumulation of clinical and demographic information. This included age, sex, body metrics (height, weight), hypertension (defined by systolic blood pressure >140 mmHg, diastolic blood pressure >90 mmHg, or ongoing antihypertensive treatment), diabetes mellitus (either previously diagnosed and under treatment, or indicated by a fasting blood sugar level >126 mg/dL), and documented coronary artery disease through patient history, physical examination, ECG, echocardiography findings, or angiographically confirmed cases.

### Exclusion Criteria

The study rigorously excluded patients with severe mitral stenosis, severe mitral regurgitation, mechanical or bioprosthetic mitral valves, and those presenting with reversible causes of AF, thus ensuring a patient cohort suitable for evaluating the specific impacts of DCCV.

### Echocardiographic Assessments

Pre-cardioversion evaluations involved advanced two-dimensional transthoracic (TTE) and transesophageal (TEE) echocardiographic examinations using high-definition GE Vivid E9 echocardiography systems equipped with a 3.5–5 MHz transducer. This dual echocardiographic approach was critical for meticulously excluding left atrial appendage (LAA) thrombus presence before proceeding with DCCV. If thrombi were identified, the cardioversion was deferred for 3–4 weeks, during which patients were administered oral anticoagulants (dabigatran or warfarin). The continuation of anticoagulation therapy was mandated for a minimum of four weeks post-procedure, with long-term therapeutic strategies adapted based on individual clinical evaluations.

### Electrical Cardioversion Procedure

Cardioversion was conducted in a highly controlled environment within the cardiac care unit (CCU), where continuous monitoring of vital parameters, including blood pressure, oxygen saturation, and ECG, was enforced. A synchronized biphasic defibrillator was utilized, delivering shocks from 100 to 200 joules. The procedure involved pre-administration of intravenous midazolam for sedation, supplemented by intravenous and maintenance doses of amiodarone, aiming for optimal control of the arrhythmia.

### Outcome Measures and Follow-Up

The primary endpoint of successful cardioversion was defined as the sustained maintenance of sinus rhythm for 24 hours post-procedure, without the recurrence of AF. Post-procedure monitoring involved meticulous follow-up for 30 days to record any instances of AF recurrence, cerebrovascular events, systemic emboli, or bleeding complications. Patients successfully maintaining sinus rhythm were continued on dabigatran or warfarin for four weeks to achieve a targeted INR of 2 to 3, with further long-term anticoagulation and antiarrhythmic therapy (amiodarone) tailored based on the patient's ongoing clinical outcomes.

### Statistical Analysis

Advanced statistical methodologies were employed to ensure robust analysis of the data. Continuous variables were scrutinized using independent t-tests, while categorical variables underwent chi-square testing. Binary logistic regression was strategically applied to identify predictors of AF recurrence. Furthermore, receiver operating characteristic (ROC) curve analysis was utilized to validate the prognostic significance of left atrial size in predicting AF recurrence.

### Ethical Considerations

The study adhered strictly to ethical guidelines approved by the institutional ethics committee. Informed consent was comprehensively obtained from all participants, ensuring full transparency about the study's aims, procedures, potential risks, and benefits.

## Results

Demographic data are illustrated in table 1, in which there was no significant difference between patients who attained sinus rhythm and remained AF in their age, BMI, gender, alcohol intake status, and smoking status.

**Table 1:** Demographic data according to AF status after cardioversion

| Variables | Successful cases | Failure cases | All | P value |
|---|---|---|---|---|
| **Number** | **46** | **11** | **57** | **-** |
| Age, years | 60.65 ± 10.69 | 59.73 ± 12.98 | 60.47 ± 11.05 | 0.806 |
| BMI, kg/m$^2$ | 31.31 ± 4.51 | 30.87 ± 5.40 | 31.22 ± 4.65 | 0.783 |
| **Gender** | | | | 0.493 |
| Female | 22 (47.8%) | 4 (36.4%) | 26 (45.6%) | |
| Male | 24 (52.2%) | 7 (63.6%) | 31 (54.4%) | |
| **Alcohol intake status** | | | | 0.428 |
| Never | 43 (93.5%) | 10 (90.9%) | 53 (93.0%) | |
| Active | 2 (4.3%) | 0 (0.0%) | 2 (3.5%) | |
| Ex-alcoholic | 1 (2.2%) | 1 (9.1%) | 2 (3.5%) | |
| **Smoking status** | | | | 0.442 |
| Never | 27 (58.7%) | 5 (45.5%) | 32 (56.1%) | |
| Active | 7 (15.2%) | 1 (9.1%) | 8 (14.0%) | |
| Ex-smoker | 12 (26.1%) | 5 (45.5%) | 17 (29.8%) | |

Table 2 summarizes the distribution of concomitant disease among the two groups. Of all the variables, DM was more prevalent in the group of patients who attained sinus rhythm than in the failure group (28.3% Vs. 0% respectively, p=0.045); whereas patients who failed to respond to DCCV were more likely to have structural heart disease than those who responded to the intervention, (45% Vs. 15.2%, respectively, p=0.027) table 2.

**Table 2:** Disease history according to post cardioversion status

| Variables | Successful cases | Failure cases | All | P value |
|---|---|---|---|---|
| Number | 46 | 11 | 57 | - |
| Hypertension | 26 (56.5%) | 5 (45.5%) | 31 (54.4%) | 0.508 |
| DM | 13 (28.3%) | 0 (0.0%) | 13 (22.8%) | 0.045 |
| Hyperthyroidism | 1 (2.9%) | 0 (0.0%) | 1 (2.3%) | 1.0 |
| IHD | 15 (32.6%) | 3 (27.3%) | 18 (31.6%) | 0.732 |
| CHF | 19 (41.3%) | 4 (36.4%) | 23 (40.4%) | 0.764 |
| Stroke | 3 (6.5%) | 1 (9.1%) | 4 (7.0%) | 1.0 |
| Pulmonary disorder | 8 (17.4%) | 0 (0.0%) | 8 (14.0%) | 0.136 |
| Mitral heart disease | 17 (37.0%) | 7 (63.6%) | 24 (42.1%) | 0.107 |
| Tricuspid heart disease | 12 (26.1%) | 6 (54.5%) | 18 (31.6%) | 0.068 |
| Structural heart disease | 7 (15.2%) | 5 (45.5%) | 12 (21.1%) | 0.027 |

Table 3 shows the distribution of disease characters among the two groups. Patients who had LAA thrombus on initial TEE assessment were more likely to fail to respond to DCCV (36% of failure cases Vs. 8.7% respectively, p=0.018). LA size was significantly higher in patients who failed to respond to DCCV (all the cases of AF recurrence had large LA size, p= 0.019). The duration of AF was higher in patient with recurrent AF however it did not reach statistical significance, as illustrated in table 3.

**Table 3:** Comparison of disease characteristics and echocardiography between sinus rhythm and AF

| Variables | Successful cases | Failure cases | All | P value |
|---|---|---|---|---|
| **Number** | **46** | **11** | **57** | **-** |
| **Anticoagulation** | | | | 0.816 |
| Warfarin | 11 (23.9%) | 3 (27.3%) | 14 (24.6%) | |
| Dabigatran | 35 (76.1%) | 8 (72.7%) | 43 (75.4%) | |
| Q wave | 9 (19.6%) | 2 (18.2%) | 11 (19.3%) | 0.917 |
| $CHA_2DS_2VAS$ | 2.61 ± 1.63 | 1.91 ± 1.30 | 2.47 ± 1.58 | 0.190 |
| **EHRA** | | | | 0.538 |
| I | 1 (2.2%) | 0 (0.0%) | 1 (1.8%) | |
| IIa | 10 (21.7%) | 2 (18.2%) | 12 (21.1%) | |
| IIb | 17 (37.0%) | 6 (54.5%) | 23 (40.4%) | |
| III | 17 (37.0%) | 2 (18.2%) | 19 (33.3%) | |
| IV | 1 (2.2%) | 1 (9.1%) | 2 (3.5%) | |
| Ventricular rate at presentation | 95.89 ± 26.36 | 89.73 ± 21.19 | 94.70 ± 25.39 | 0.474 |
| Duration of AF | 23.5 (10-78) | 104 (26-104) | 26 (12-104) | 0.067 |
| <12 weeks | 12 (26.1%) | 1 (9.1%) | 13 (22.8%) | 0.227 |
| ≥12 weeks | 34 (73.9%) | 10 (90.9%) | 44 (77.2%) | |
| LVH | 25 (54.3%) | 6 (54.5%) | 31 (54.4%) | 0.991 |
| EF% | 53.52 ± 12.18 | 57.36 ± 12.36 | 54.26 ± 12.20 | 0.353 |
| LA size | 41.02 ± 4.47 | 44.45 ± 2.84 | 41.68 ± 4.40 | 0.019 |
| Left atrial appendage thrombus | 4 (8.7%) | 4 (36.4%) | 8 (14.0%) | 0.018 |

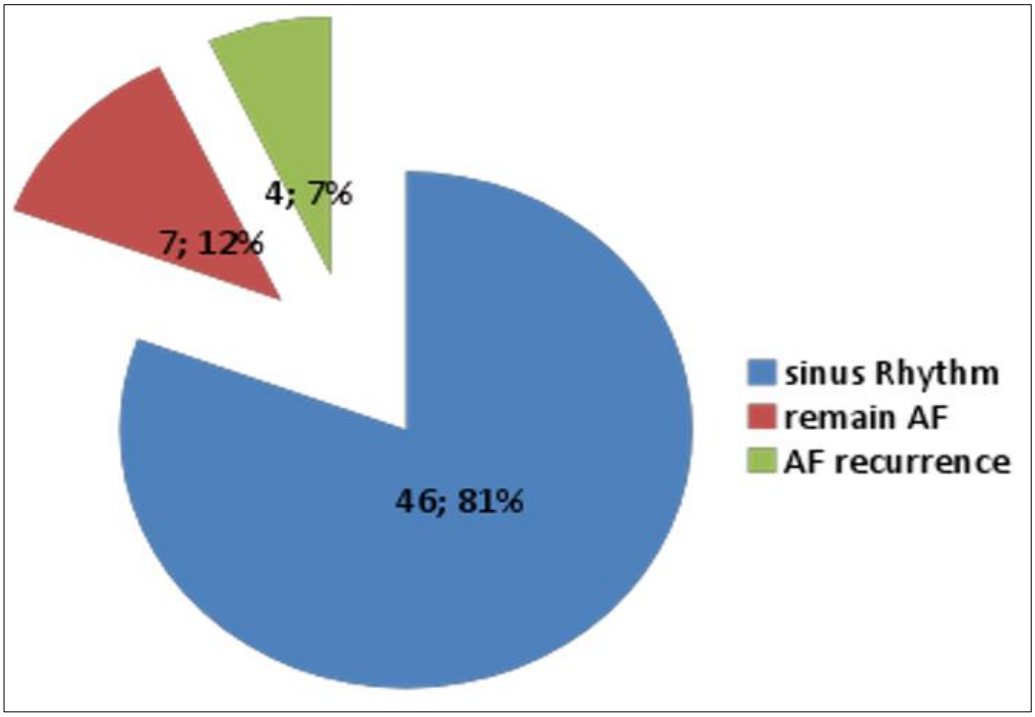


**Fig 1:** Outcome of cardioversion in patients with AF

Tricuspid valve disease, mitral valve disease, gender were weakly predict AF recurrence, while the rest of the variable did not predict AF recurrence as illustrated in Table 4.

**Table 4:** Predictors of AF recurrence

| Variables | OR | 95%CI | P value |
|---|---|---|---|
| Age | 0.990 | 0.902-1.087 | 0.836 |
| Gender | 2.750 | 0.266-28.433 | 0.396 |
| BMI | 0.948 | 0.741-1.213 | 0.672 |
| Duration of AF | 1.0 | 0.986-1.013 | 0.946 |
| Mitral valve disease | 5.118 | 0.492-53.182 | 0.172 |
| Tricuspid valve disease | 8.500 | 0.805-89.746 | 0.075 |
| VR at presentation | 0.958 | 0.899-1.020 | 0.177 |
| LVH | 0.840 | 0.109-6.486 | 0.867 |
| EF% | 0.995 | 0.913-1.083 | 0.900 |
| LA size | 1.223 | 0.958-1.560 | 0.106 |
| Binary logistic regression analysis | | | |

LA size has fair ability (since the AUC between 0.7-0.79) to predict the recurrence of AF in patients, with an optimal cut point of >41 mm to predict AF recurrence, having higher sensitivity compared to specificity, indicating it may be useful as screening predictor more than confirmatory predictor, as illustrated in table 4 and figure 2.

**Table 5:** Validity of LA size as predictor of AF recurrence

| AUC | P value | Optimal cut point | Sensitivity | Specificity | PPV | NPV |
|---|---|---|---|---|---|---|
| 0.766 | 0.004 | >41 | 100% | 58.7% | 17.4% | 100% |

ROC analysis

AUC: area under the curve, PPV: positive predictive value, NPV: negative predictive value

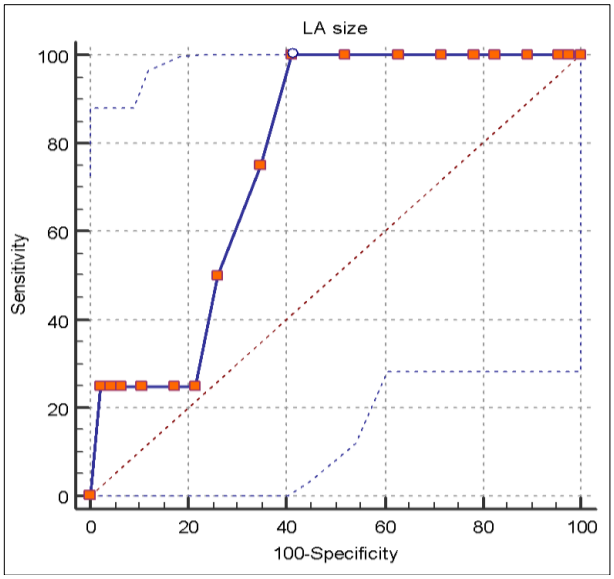


**Fig 2:** ROC curve analysis of LA size as predictor of AF recurrence

## Discussion

In the present study, the intermediate-term success rate of electrical cardioversion (ECV) in restoring sinus rhythm (SR) in patients with atrial fibrillation (AF) was found to be 80.7%. This outcome is comparable to, or exceeds, the success rates reported in numerous other clinical investigations focusing on the predictors of ECV success and the recurrence of AF (Frick *et al*., 2001) [11]. Notably, electrical cardioversion has consistently shown superiority over pharmacologic cardioversion in achieving SR in patients with persistent AF, as evidenced by studies such as that by Fujiki *et al*. (2006) [10], which reported a success rate of 67% for pharmacological conversion. Our study corroborates the efficacy of electrical over pharmacological conversion, echoing findings from Elesber *et al*. (2006) [9] and Easley and Li (1998), who reported electrical cardioversion success rates exceeding 90%. In this cohort, factors such as tricuspid valve disease and mitral valve disease emerged as predictors of AF recurrence, albeit with weak associations as indicated by their wide confidence intervals (OR=8.500, 95%CI=0.805-89.746 and OR=5.118, 95%CI=0.492-53.182, respectively). These findings align with those reported by Van Gelder *et al*. (1991), who noted the importance of arrhythmia duration and the type of arrhythmia in predicting ECV success. Interestingly, large left atrial (LA) size was also identified as a significant predictor of recurrence, demonstrating a fair predictive ability (AUC=0.766), with an optimal cut-off point of >41 mm (Marchese *et al*., 2011) [14]. This is consistent with studies within the AFFIRM analysis where LA diameter was highlighted as a crucial predictor of AF recurrence (Kosior *et al*., 2006; Raitt *et al*., 2006) [13, 16]. Further complicating the clinical landscape, cardiopulmonary diseases such as chronic obstructive pulmonary disease and obstructive sleep apnea have been shown to have a possible causal relationship with AF and its recurrence, likely due to the dilated right atrium (RA) associated with tricuspid regurgitation (TR) (Kanagala *et al*., 2003) [12]. These conditions could explain why tricuspid valve disease was a predictor of poor outcomes in our study, potentially reflecting long-standing AF sufficient to cause RA remodeling and tricuspid regurgitation. Additionally, the duration of AF has consistently correlated with a lower success rate and the recurrence of the arrhythmia (Sopher & Camm, 1996) [17]. In our study, although the difference in AF duration between successful and unsuccessful ECV groups was not statistically significant (p=0.067), there was a notable trend suggesting longer AF duration in the unsuccessful group, which could be due to the small sample size and shorter follow-up duration limiting the statistical power of our analysis. Moreover, a significant finding in our study was the 14% prevalence of atrial thrombi among patients, with large LA size and poor LAA contractility identified as predictors for the presence of thrombi and AF recurrence. Diabetes, which is frequently co-occurring with AF, emerged as a complex factor in our study, influencing outcomes in a manner that suggests an intricate interplay with other variables like AF duration and LA size. Despite the higher success rate in maintaining sinus rhythm compared to other studies, likely influenced by the prevalent use of antiarrhythmic drugs, ACE inhibitors, and beta-blockers in our cohort, which reduce triggers for AF recurrence (Corley *et al*., 2004) [8], the study's findings must be viewed within the context of its limitations, including its smaller sample size and the short duration of follow-up. Nonetheless, this investigation adds valuable insights into the complex dynamics influencing the success of ECV and highlights the critical role of comprehensive management strategies to optimize patient outcomes (McNamara *et al*., 2003) [15].

## Conclusion

This study robustly demonstrates the superior efficacy of electrical cardioversion (ECV) in restoring sinus rhythm in patients with atrial fibrillation (AF), achieving an impressive intermediate-term success rate of 80.7%. These findings not only confirm the effectiveness of ECV compared to pharmacological methods but also highlight it as a cornerstone in the management of persistent AF. Our research has delineated several key predictors of AF recurrence, with tricuspid and mitral valve diseases being identified, albeit with weaker statistical associations. Significantly, the left atrial (LA) size has emerged as a strong predictive factor for AF recurrence, reinforcing its critical role in clinical evaluations and decisions regarding the management of AF. The study also sheds light on the multifaceted nature of AF recurrence, where cardiopulmonary conditions, such as chronic obstructive pulmonary disease and obstructive sleep apnea, have been shown to exacerbate the condition likely due to associated right atrial dilation and tricuspid regurgitation. The intricacies of these associations underline the complexity of AF management and the necessity for a holistic approach that considers both cardiac and extracardiac factors. Furthermore, the unexpected influence of diabetes on ECV outcomes points to an intricate interplay of metabolic factors with cardiac electrophysiology, suggesting a potential avenue for further research into metabolic management as part of AF treatment protocols. Despite achieving a high success rate, the constraints of this study, including its small sample size and relatively short follow-up period, necessitate further investigation. Future studies should aim to validate these findings in larger cohorts over longer durations to ensure the generalizability and sustainability of the results. In conclusion, this study not only reinforces the efficacy of ECV in treating AF but also advances our

understanding of the predictors of success and recurrence, advocating for tailored treatment strategies that address the specific needs and risk profiles of individual patients. It underscores the imperative for ongoing research to refine therapeutic approaches and improve outcomes for patients suffering from this challenging cardiac arrhythmia.

**Conflict of Interest**
Not available

**Financial Support**
Not available

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