



# Low efficacy of cardioversion of persistent atrial fibrillation with the implantable cardioverter-defibrillator

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## Abstract

**Aims** Atrial fibrillation (AF) and heart failure are conditions that often coexist. Consequently, many patients with an implantable cardioverter-defibrillator (ICD) present with AF. We evaluated the effectiveness of internal cardioversion of AF in patients with an ICD.

**Methods** Retrospectively, we included 27 consecutive ICD patients with persistent AF who underwent internal cardioversion using the ICD. When ICD cardioversion failed, external cardioversion was performed.

**Results** Patients were predominantly male (89 %) with a mean (SD) age of 65±9 years and left ventricular ejection fraction of 36±17 %. Only nine (33 %) patients had successful internal cardioversion after one, two or three shocks. The remaining 18 patients underwent external cardioversion after they failed internal cardioversion, which resulted in sinus rhythm in all. A smaller left atrial volume (99±36 ml vs. 146±44 ml;  $p=0.019$ ), a longer right atrial cycle length (227 (186–255) vs. 169 (152–183) ms,  $p=0.030$ ), a shorter total AF history (2 (0–17) months vs. 40 (5–75) months,  $p=0.025$ ) and dual-coil ICD shock (75 % vs. 26 %,  $p=0.093$ ) were associated with successful ICD cardioversion.

**Conclusion** Internal cardioversion of AF in ICD patients has a low success rate but may be attempted in those with small atria, a long right atrial fibrillatory cycle length and a short total AF history, especially when a dual-coil ICD is present. Otherwise, it seems reasonable to prefer external

over internal cardioversion when it comes to termination of persistent AF.

**Keywords** Atrial fibrillation · Implantable cardioverter defibrillator · Internal cardioversion

## Introduction

Persistent atrial fibrillation (AF) can be terminated by pharmacological or electrical cardioversion. Electrical cardioversion is effective in about 86–95 % of patients [1–3].

In patients with an implantable cardioverter-defibrillator (ICD), AF can be cardioverted with a synchronised internal shock from the ICD. Only limited data are available on the efficacy of internal ICD cardioversion for AF [4]. In the present study, we evaluated the effectiveness of internal cardioversion of AF in ICD patients.

## Methods

From our prospective electronic ICD database we retrospectively identified 27 patients with persistent AF who underwent elective cardioversion using the ICD between 2007 and 2012. In our hospital, cardioversion by means of ICD is the first choice in patients with persistent AF who have an ICD. Persistent AF was defined as an episode of non-self-terminating AF lasting at least 7 days, confirmed by electrocardiography [5]. Peri-cardioversion patients received appropriate oral anticoagulation according to the ESC guidelines for the management of AF [5]. Baseline and procedural characteristics were extracted from medical charts using the hospital electronic data system. Specifications of ICDs were retrieved from our ICD database. When available, the atrial fibrillation cycle length (AFCL) was measured from the intracardiac

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recordings. The average of at least 10 consecutive AFCLs was used. Recurrence of AF was defined as AF lasting at least 30 s documented on 12-lead ECG or registered by intracardiac recordings available from the ICD. LV dimensions, LV ejection fraction and atrial dimensions was measured according to the recommendations as described in the American Society of Echocardiography guidelines. This retrospective analysis was approved by the local Ethics Committee and complied with the Declaration of Helsinki.

### Procedures

Patients had to be in a fasting state before the procedure. After sedation (propofol or etomidate), internal cardioversion with the ICD was performed in all patients. Internal cardioversion was carried out by the ICD technician in the presence of the attending physician. An internal biphasic shock was given synchronised with the ventricular electrogram. If, in case of failure, a second internal shock was attempted, this was performed using reversed polarity. All patients received at least one shock from the ICD using the maximum shock energy of the device (at least 31 J, range between 31 and 41 J). ICDs were from Medtronic ( $n=19$ ), Boston Scientific ( $n=7$ ), and St. Jude Medical ( $n=1$ ). The number of shocks was decided by the attending physician. Success of cardioversion was defined as termination of AF and the presence of two or more consecutive P waves aftershock documented on the 12-lead surface ECG. If internal cardioversion failed, an external direct current shock synchronised to the ventricular R wave was performed using a biphasic shock (Lifepak® defibrillator, Medtronic Inc, Minnesota, USA) with handheld paddles or self-adhesive pads in the anterior–posterior position with the patient in a left or right lateral recumbent position. Shocks were delivered starting at 200 or 360 J stored energy, decided by the attending physician. If AF persisted, one additional shock was applied using 360 J. Following internal and external cardioversion the ICD was interrogated for changes in sensing threshold, pacing threshold and pacing impedance.

### Statistical analysis

Data analysis was performed using SPSS statistical software (SPSS, Inc., release 18.0). The Kolmogorov–Smirnov test was used to test the continuous variables for normal distribution. The continuous variables are reported as mean  $\pm$  standard deviation when normally distributed and as median and interquartile range (IQR 25th percentile–75th percentile) when distribution was not normal. Categorical variables are reported as observed number of patients (percentage). Differences between parameters with normal distribution were tested with an independent t-test and with abnormal distribution with the Mann–Whitney test. Fisher’s exact test was used to

compare categorical variables. A  $p$ -value of  $<0.05$  was considered to be statistically significant.

## Results

### Baseline characteristics

The baseline characteristics are presented in Table 1. Nine of 27 patients were treated with anti-arrhythmic drugs (AAD) with the majority using amiodarone. Dilated cardiomyopathy was the main reason for ICD implantation (66 %). Four out of 27 patients had a dual-coil ICD lead. In 2 patients the ICD was located in the right pre-pectoral region, in the other patients the ICD was in the left part. In all patients the shock lead was placed in the apex of the right ventricle. Echocardiograms were performed at a median of 5 (IQR 2–12) months before cardioversion.

### Cardioversion efficacy by ICD shock

Cardioversion with the ICD resulted in sinus rhythm in only 9 of 27 patients (33 %). AF was terminated with one shock in seven patients, with two in one patient and one needed three shocks (Fig. 1). The median maximum energy delivered by the ICD for successful cardioversion was 35 (35–38) Joules. Patients with a failed internal cardioversion received one ( $n=9$ ) or two ( $n=9$ ) shocks by the ICD with a median maximum shock of 35 (35–36) Joules. In all these 18 patients, external electrical cardioversion resulted in sinus rhythm after one or two shocks, in 16 and 2 patients respectively. The median shock energy for successful cardioversion was 200 (200–360) joules. No adjustments to the ICD settings were necessary following interrogations of the ICD after cardioversion.

### Factors associated with successful ICD cardioversion

Patients with successful ICD cardioversion had significantly smaller left atrial volumes ( $99\pm 36$  ml vs.  $146\pm 42$  ml;  $p=0.019$ ) and a trend towards smaller right atrial volumes ( $77$  (73–86) ml vs.  $104$  (77–136) ml,  $p=0.07$ ) compared with patients in whom internal cardioversion failed. In addition, in patients with acute successful internal electrical cardioversion there was a significantly shorter history of AF (2 (0–17) months vs. 40 (5–75) months,  $p=0.025$ ) and a trend to a shorter current episode of AF (39 (16–133) days vs. 103 (41–182) days  $p=0.28$ ). Three out of four patients with a dual-coil ICD had successful internal electrical cardioversion. Pre-cardioversion atrial fibrillatory cycle length could be assessed in 16 patients and was significantly longer in patients with successful conversion ( $227$  (186–255) vs.  $169$  (152–183) ms,  $p=0.030$ ). Of

**Table 1** Baseline characteristics of patients who had no conversion to SR after internal ICD shock versus patients who had successful conversion to SR

	All <i>N</i> =27	No SR after ICD shock <i>N</i> =18 (67 %)	SR after ICD shock <i>N</i> =9 (33 %)	<i>P</i> -value
Age (years)	65±9	65±10	65±8	0.89
Male	24 (89 %)	16 (89 %)	8 (89 %)	1.00
Body surface area (m <sup>2</sup> )	2.0±0.2	1.9±0.2	2.0±0.2	0.48
Total AF history (months)	22 (3–63)	40 (5–75)	2 (0–17)	0.025
Duration of current AF episode (days)	101 (32–155)	103 (41–182)	39 (16–133)	0.28
Medical history				
Hypertension	18 (67 %)	7 (39 %)	2 (22 %)	0.67
Coronary arterial disease	19 (70 %)	14 (78 %)	5 (56 %)	0.38
Diabetes mellitus	5 (19 %)	4 (22 %)	1 (11 %)	0.64
Stroke	0	0	0	1.00
Transient ischaemic attack	2 (7 %)	1 (6 %)	1 (11 %)	1.00
Heart failure	18 (67 %)	12 (67 %)	6 (67 %)	1.00
Medication				
Acenocoumarol	27 (100 %)	18 (100 %)	9 (100 %)	1.00
Sotalol	2 (7 %)	1 (6 %)	1 (11 %)	0.53
Amiodarone	7 (26 %)	5 (28 %)	2 (22 %)	1.00
Flecainide	0	0	0	1.00
Beta-blocker	24 (89 %)	16 (89 %)	8 (89 %)	1.00
ACE-inhibitor or ATII-antagonist	21 (78 %)	14 (78 %)	7 (78 %)	1.00
Statin	19 (70 %)	12 (67 %)	7 (78 %)	0.38
Echocardiographic parameters				
LV ejection fraction (%)	36±17	34±18	40±16	0.39
Diameter LA (mm)	51±6	52±7	49±5	0.29
Volume LA (cc)	132±35	146±44	99±36	0.019
Volume RA (cc)	89 (76–110)	104 (77–136)	77 (73–86)	0.07
LV end-diastolic diameter (mm)	61±10	61±38	59±9	0.62
LV end-systolic diameter (mm)	50±14	51±14	47±12	0.55
ICD details				
Indication for ICD				
- Non-ischaemic cardiomyopathy	6 (22 %)	3 (17 %)	3 (33 %)	
- Post-infarction cardiomyopathy	12 (44 %)	8 (44 %)	4 (44 %)	
- Hypertrophic cardiomyopathy	3 (11 %)	2 (11 %)	1 (11 %)	
- Unclassified	6 (22 %)	5 (28 %)	1 (11 %)	
Single coil	23 (85 %)	17 (94 %)	6 (67 %)	0.09
Atrial cycle length (ms, <i>N</i> =16)	175 (157–211)	169 (152–183)	227 (186–255)	0.030

Results are shown as number (%) or as mean ± SD when equally distributed and as median (interquartile range) when there was no normal distribution  
*LA* left atrium; *LV* left ventricular; *RA* right atrium; *SR* sinus rhythm

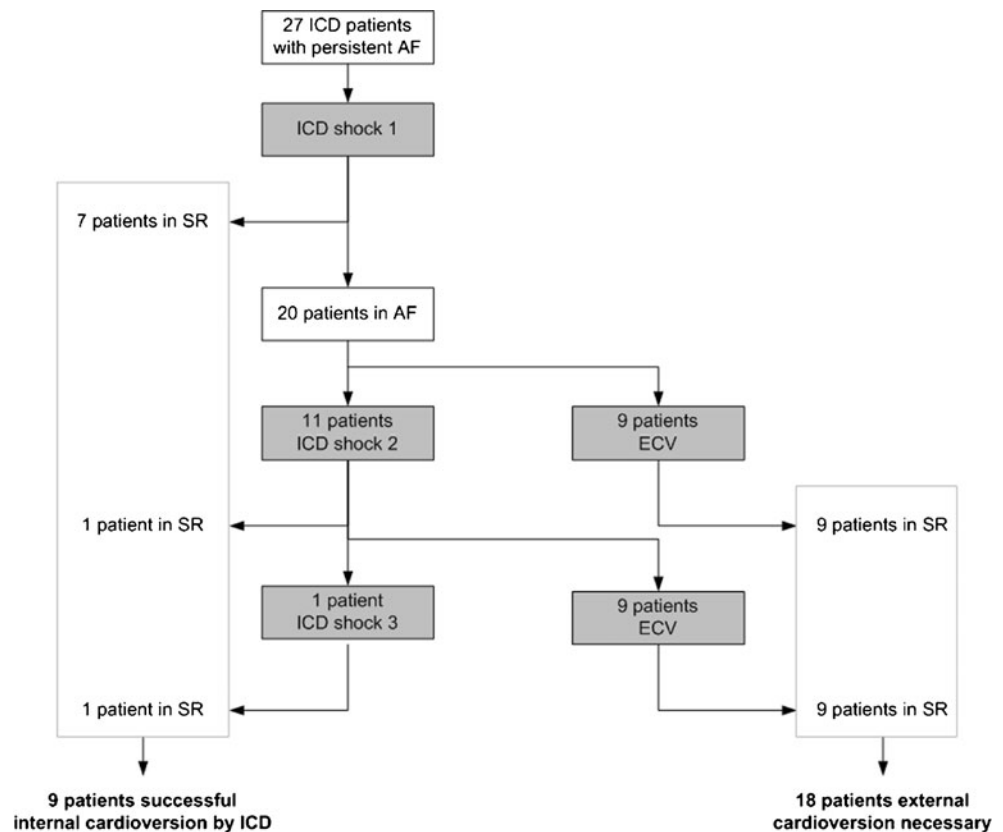
the 9 patients using AADs, only 3 (33 %) converted to sinus rhythm with the ICD compared with 6 of 18 (33 %) patients not using AADs.

#### Follow-up

Recurrence of AF after 1 year of follow-up occurred in 18 out of 27 patients (67 %). There was a trend towards a higher recurrence rate in the group with failed internal cardioversion compared with the group who had successful internal

cardioversion (78 % vs. 44 %, *p*=0.11). There was no difference in AF cycle length in patients with or without recurrence (176 (150–203) vs. 172 (158–250) ms, *p*=0.83) respectively. The current AF episode duration (prior to ECV) did not differ significantly between those with and without an AF recurrence within 1 year (85 (39–133) vs. 102 (20–223) days; *p*=0.87) respectively. Furthermore, no significant echocardiographic differences were observed between patients with and without an AF recurrence during 1-year follow-up (data not shown).

**Fig. 1** Flowchart of ICD cardioversions and external electrical cardioversion (ECV). SR denotes sinus rhythm



## Discussion

The main finding of the present study is that internal cardioversion by means of ICD shock results in conversion to sinus rhythm in only one third of patients. Factors associated with successful conversion in our study include smaller left atrium, longer right atrial fibrillatory cycle length, shorter total AF duration and use of dual-coil rather than single-coil ICD shocks. Our data support the notion that internal cardioversion of persistent AF in patients with single-coil ICD should be reserved for patients with a favourable arrhythmia profile.

Factors associated with successful cardioversion with an ICD

Only limited data are available on the cardioversion efficacy in persistent AF using the ICD. Two studies showed high cardioversion efficacy of ICD shocks in patients with paroxysmal or acutely induced AF [6, 7]. Turco et al. [4] evaluated cardioversion efficacy of ICD shocks in patients with a CRT-D device and permanent AF for more than 1 year. They found that 82 % of patients could be converted to stable sinus rhythm. The difference with our study concerning conversion efficacy is remarkable. Patients were very similar concerning parameters known to be associated with successful cardioversion including AF duration, and left ventricular and atrial sizes. However, in their study, the conversion procedure was

only performed after at least 3 months of biventricular pacing which may have optimised atrial electrophysiology before conversion. In addition, all patients were pretreated with amiodarone which enhances electrical cardioversion [8, 9]. Also, their cardioversion protocol required as many as 3 shocks before cessation of the cardioversion attempt. Finally, although not reported in the manuscript [4], all patients had dual-coil defibrillator leads (personal communication with the authors). It is well known that the shock vector, determined by the position of the shock coil(s) and the can of the ICD, has major impact on shock efficacy. For defibrillation of ventricular arrhythmias the defibrillation threshold is, for example, higher when the can is placed in the right rather than the left sub-pectoral position [10]. With respect to atrial arrhythmias it was previously shown that dual-coil shocks are associated with a lower atrial defibrillation threshold [7]. Electrical cardioversion of AF with temporary internally placed catheters in the right atrium and coronary sinus is associated with a high cardioversion efficacy [11–13]. The internal defibrillation catheters were encompassing both atria, producing the most ideal shock vector for atrial defibrillation.

In our study population the majority of patients had a single-coil shock lead located in the right ventricle. This resulted in a less ideal shock vector for atrial defibrillation, which may explain the low cardioversion efficacy. Although

the number of patients with dual coils was small in the present study, cardioversion efficacy was indeed remarkably higher in patients with a dual coil (75 %, 3 out of 4) compared with single coil (26 %, 6 out of 23). Worldwide, dual-coil ICD lead systems are more popular than single-coil ICD systems [14]. The main reason that the majority in this study population had a single-coil lead is the difficult extraction procedure of dual-coil leads due to the location in the proximal coil [15].

Many other factors may influence acute external cardioversion outcome, including AF duration, atrial size, patient age, presence of heart failure or structural heart disease, and pre-treatment with drugs [3, 8, 16–18]. One interesting finding in the present study was the association between long atrial fibrillatory cycle length, as measured from an atrial electrogram from the atrial pacing lead, and high internal cardioversion efficacy. Shortening of the atrial refractory period and hence also of the atrial fibrillatory cycle length is associated with increasing electrophysiological complexity and reduced response to anti-arrhythmic treatment [19–22]. A short cycle length may therefore represent an advanced atrial substrate. This supports the notion that a longer atrial fibrillatory cycle length as measured from the atrial lead in the device may help identify AF patients who may respond to internal atrial defibrillation.

In this study the AF recurrence rate after 1-year follow-up is comparable with that seen after external cardioversion [23]. This is somewhat surprising since most patients in the present study had significant structural heart disease with the majority having reduced systolic LV function a marked atrial dilation. Interestingly, patients who underwent successful internal cardioversion had a recurrence rate of only 44 %. Although the number of patients is too small to draw a firm conclusion, it is tempting to speculate that these patients had a less advanced atrial substrate since they responded to single-coil internal cardioversion.

### Limitations

Although we collected data prospectively in our pacemaker and ICD database, this study was retrospective and at best reflects real-life internal cardioversion practice. The majority of patients had a single-coil ICD hampering drawing conclusions for dual-coil configurations. Nevertheless, the findings concerning the effects of (single-coil) ICD shocks are noteworthy, especially since data concerning clinical internal ICD cardioversion of persistent AF are largely lacking. A randomised study comparing external cardioversion and ICD cardioversion with inclusion of more patients would be desirable. However, due to the remarkable low success percentage of internal cardioversion, our protocol has been adapted and the first choice is external cardioversion for persistent AF in patients with an ICD.

### Clinical implications and conclusion

In patients with an ICD, clinicians are often confronted with troublesome AF [24–26] which may need cardioversion to ameliorate symptoms and potentially unfavourable haemodynamics. Currently, there are no guidelines on whether or not internal atrial defibrillation is appropriate in patients with an ICD presenting with persistent AF. The present study suggests that internal ICD shocks are largely ineffective in this respect, especially in case of single-coil shocks. In the presence of a single-coil ICD, internal cardioversion may, however, be considered if patients harbour a favourable arrhythmia profile including smaller atrial volume, longer right atrial cycle length and shorter AF history. Otherwise, it seems reasonable to prefer external over internal cardioversion when it comes to terminating persistent AF. In this way, unnecessary unsuccessful shocks by the ICD can be prevented and in addition earlier battery depletion and prolonged sedation duration during cardioversion can be minimised.

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### References

- Berry C, Stewart S, Payne EM, et al. Electrical cardioversion for atrial fibrillation: outcomes in “real-life” clinical practice. *Int J Cardiol.* 2001;81(1):29–35.
- Blich M, Edoute Y. Electrical cardioversion for persistent or chronic atrial fibrillation: outcome and clinical factors predicting short and long term success rate. *Int J Cardiol.* 2006;107(3):389–94.
- Pisters R, Nieuwlaet R, Prins MH, et al. Clinical correlates of immediate success and outcome at 1-year follow-up of real-world cardioversion of atrial fibrillation: the Euro Heart Survey. *Europace.* 2012;14(5):666–74.
- Turco P, D’Onofrio A, Stabile G, et al. Feasibility and efficacy of electrical cardioversion after cardiac resynchronization implantation in patients with permanent atrial fibrillation. *J Interv Card Electrophysiol.* 2012;35(3):331–6.
- Camm AJ, Kirchhof P, Lip GY, et al. Guidelines for the management of atrial fibrillation: the Task Force for the Management of Atrial Fibrillation of the European Society of Cardiology (ESC). *Eur Heart J.* 2010;31(19):2369–429.
- Crossley GH, Aonuma K, Haffajee C, et al. Atrial fibrillation therapy in patients with a CRT defibrillator with wireless telemetry. *Pacing Clin Electrophysiol.* 2009;32(1):13–23.
- Rashba EJ, Shorofsky SR, Peters RW, et al. Optimization of atrial defibrillation with a dual-coil, active pectoral lead system. *J Cardiovasc Electrophysiol.* 2004;15(7):790–4.



8. Van Noord T, Van Gelder IC, Crijns HJ. How to enhance acute outcome of electrical cardioversion by drug therapy: importance of immediate reinitiation of atrial fibrillation. *J Cardiovasc Electrophysiol*. 2002;13(8):822–5.
9. Van Noord T, Van Gelder IC, Schoonderwoerd BA, et al. Immediate reinitiation of atrial fibrillation after electrical cardioversion predicts subsequent pharmacologic and electrical conversion to sinus rhythm and amiodarone. *Am J Cardiol*. 2000;86 12:1384–5, A5
10. Gold MR, Shih HT, Herre J, et al. Comparison of defibrillation efficacy and survival associated with right versus left pectoral placement for implantable defibrillators. *Am J Cardiol*. 2007;100(2):243–6.
11. Levy S, Ricard P, Lau CP, et al. Multicenter low energy transvenous atrial defibrillation (XAD) trial results in different subsets of atrial fibrillation. *J Am Coll Cardiol*. 1997;29(4):750–5.
12. Boriani G, Biffi M, Camanini C, et al. Efficacy of internal cardioversion for chronic atrial fibrillation in patients with and without left ventricular dysfunction. *Int J Cardiol*. 2004;95(1):43–7.
13. Tse HF, Lau CP. Safety and efficacy of internal cardioversion of atrial fibrillation in patients with impaired left ventricular systolic function. *Am J Cardiol*. 1999;84 9:1090–2, A9.
14. Neuzner J, Carlsson J. Dual- versus single-coil implantable defibrillator leads: review of the literature. *Clin Res Cardiol*. 2012;101(4): 239–45.
15. Bracke F. Complications and lead extraction in cardiac pacing and defibrillation. *Neth Heart J*. 2008;16 Suppl 1:S28–31.
16. Frick M, Frykman V, Jensen-Urstad M, et al. Factors predicting success rate and recurrence of atrial fibrillation after first electrical cardioversion in patients with persistent atrial fibrillation. *Clin Cardiol*. 2001;24(3):238–44.
17. Mittal S, Ayati S, Stein KM, et al. Transthoracic cardioversion of atrial fibrillation: comparison of rectilinear biphasic versus damped sine wave monophasic shocks. *Circulation*. 2000;101(11):1282–7.
18. Van Gelder IC, Crijns HJ, Van Gilst WH, et al. Prediction of uneventful cardioversion and maintenance of sinus rhythm from direct-current electrical cardioversion of chronic atrial fibrillation and flutter. *Am J Cardiol*. 1991;68(1):41–6.
19. Boahene KA, Klein GJ, Yee R, et al. Termination of acute atrial fibrillation in the Wolff-Parkinson-White syndrome by procainamide and propafenone: importance of atrial fibrillatory cycle length. *J Am Coll Cardiol*. 1990;16(6):1408–14.
20. Capucci A, Biffi M, Boriani G, et al. Dynamic electrophysiological behavior of human atria during paroxysmal atrial fibrillation. *Circulation*. 1995;92(5):1193–202.
21. Haissaguerre M, Lim KT, Jacquemet V, et al. Atrial fibrillatory cycle length: computer simulation and potential clinical importance. *Europace*. 2007;9 Suppl 6:vi64–70.
22. Wijffels MC, Kirchhof CJ, Dorland R, et al. Atrial fibrillation begets atrial fibrillation. A study in awake chronically instrumented goats. *Circulation*. 1995;92(7):1954–68.
23. Kim SK, Pak HN, Park JH, et al. Clinical and serological predictors for the recurrence of atrial fibrillation after electrical cardioversion. *Europace*. 2009;11(12):1632–8.
24. Anter E, Jessup M, Callans DJ. Atrial fibrillation and heart failure: treatment considerations for a dual epidemic. *Circulation*. 2009;119(18):2516–25.
25. Maisel WH, Stevenson LW. Atrial fibrillation in heart failure: epidemiology, pathophysiology, and rationale for therapy. *Am J Cardiol*. 2003;91(6A):2D–8.
26. McManus DD, Shaikh AY, Abhishek F, et al. Atrial fibrillation and heart failure parallels: lessons for atrial fibrillation prevention. *Crit Pathw Cardiol*. 2011;10(1):46–51.



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