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Strategies for Successful Electrical Cardioversion in Atrial Fibrillation

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Abstract

Atrial fibrillation (AF) is the most common arrhythmia in the world, and its management relies on restoring sinus rhythm through external electrical shock and controlling the heart rate. This procedure should be performed under sedation with strict monitoring of blood pressure and saturation after the elimination of thrombus in the left atrium. **Objective**: The aim of this article is to provide an overview of the impact of anticoagulation and imaging in the periprocedural period, the modalities, and the complications associated with electrical cardioversion (ECV). **Research Method**: A review of recent literature was conducted using medical databases such as PubMed and Scopus. Searches were performed on articles published between 2003 and 2024, focusing on the new ESC guidelines for 2024. The keywords used included "electrical cardioversion", "atrial fibrillation", "orthogonal cardioversion" and "anticoagulation". Inclusion criteria encompassed clinical trials, meta-analyses, and literature reviews, while studies addressing other treatment forms for AF or lacking information on ECV were excluded. Relevant data were extracted and synthesized to provide an overview of the modalities and complications related to ECV in the context of AF. **Results and Conclusion**: The use of high-energy biphasic shocks significantly improves rhythm control success and also reduces the incidence of ventricular fibrillation. Furthermore, orthogonal electrical cardioversion (OECV) has proven effective for cases of AF refractory to standard protocols, allowing for a lower defibrillation threshold and promoting better current distribution. However, complications must be considered, particularly thromboembolic events in non-anticoagulated patients. Other complications, such as bradycardia and recurrence of AF, may arise post-procedure. It is therefore crucial to ensure adequate anticoagulation before and after ECV, as well as continuous monitoring, to minimize these risks and optimize clinical outcomes.

Keywords

Atrial Fibrillation, Electrical Cardioversion, Anticoagulation, Anti-Arrhythmic

1. Introduction

Atrial fibrillation (AF) is the most common arrhythmia encountered in clinical practice, and commonly leads to morbidity and mortality as a result of thromboembolism events or heart failure. The prevalence for AF increases with aging, and there are predictable geographic variabilities in the presentation of these diseases [1]. Fundamental mechanisms of AF are still poorly elucidated; though extensive research has been conducted. Management of this condition is best done with a combined approach including rhythm and rate control.

Electrical cardioversion (ECV) effectively restores sinus rhythm and alleviates symptoms with little to no changes in disease progression. Nonetheless, this process is certainly not harmless with regard to thromboembolic and rhythmic issues.

The present article offers a review of what is known about the various methods and techniques to perform ECV for AF, concentrating on new available technologies like high-energy biphasic shocks and orthogonal shock delivery, focusing as well in complications associated with this procedure. This paper sets to guide practitioners through the current literature on best practice of cardioversion in AF by reviewing the recommendations made by health bodies.

2. Incidence and Prevalence of AF

AF affects approximately 33 million people worldwide, including more than 3 million in the United States. By 2030, the annual incidence of AF in the U.S. is projected to reach 2.6 million new cases, with the prevalence potentially climbing to 12.1 million [1]-[3]. Findings from the Framingham study indicate that both the incidence and prevalence of AF are on the rise. However, this increase is accompanied by improved survival rates, largely due to advancements in management strategies.

3. Cardioversion of AF

Management of AF emphasizes the new FA-CARE concept, which includes: **C** for managing comorbidities, **A** for anticoagulation, **R** for reducing symptoms through rhythm and rate control, and **E** for ongoing assessment and reassessment according to the 2024 recommendations from the European Society of Cardiology (ESC).

3.1. Anticoagulation

Direct oral anticoagulants (DOACs) or vitamin K antagonists (VKAs) are the first-line treatment to prevent thromboembolic events in AF patients. The 2024 recommendations advise VKAs for patients with valvular AF (such as moderate to severe mitral stenosis or mechanical prostheses), irrespective of their CHA_2DS_2-VA score. Conversely, DOACs are preferred for non-valvular AF, especially for those with a CHA_2DS_2-VA score of 2 or more, elderly patients with cognitive impairment or poor compliance, and those with a therapeutic range under VKAs (TTR) below 70% [2] [4].

Recently, DOACs may also be considered for patients with asymptomatic subclinical AF detected by devices who are at high thromboembolic risk. Evaluating bleeding risk should be an integral part of routine AF management, which includes addressing modifiable bleeding risk factors such as uncontrolled hypertension, unstable international normalized ratio (INR), concurrent use of antiplatelet, excessive alcohol consumption, and anemia [5] [2].

Prevention of stroke with adjusted-dose warfarin has been demonstrated to be more effective than aspirin alone or in combination with clopidogrel, and aspirin alone is no longer recommended for preventing cardio embolic strokes [1] [5]. In cases where anticoagulants are contraindicated, percutaneous closure of the left atrial (LA) appendage is an alternative option to prevent thromboembolic events [1] [2].

3.1.1. Anticoagulation in Pericardioversion

Oral anticoagulation should be initiated for all patients with AF > 24 hours or of unknown duration who are scheduled for cardioversion, at least three weeks prior to the procedure (with adherence to DOAC protocols or an INR greater than 2 if using VKAs). Early cardioversion can be safely carried out if no thrombus is detected in the left atrium via trans-esophageal echocardiogram (TEE). If a thrombus is present, adequate anticoagulation should be initiated for at least 3 weeks before repeating the TEE to confirm that the thrombus has resolved [6] [7].

Recent trials have provided evidence for DOACs using cardioversion; however, no standardized test to assess the DOAC effects in patients undergoing a procedure is currently available [6].

3.1.2. Imaging Prerogative in Cardioversion

TEE is the point-of-reference standard in advance for ruling out thrombus creation before cardioversion. Its sensitivity is enhanced by the use of ultrasound contrast agents, 3-dimensional TEE, and tissue Doppler imaging [7]-[9]. Flow velocities of less than 40 cm/s [6] and the presence of spontaneous echo contrast may provide additional indirect evidence for LA thrombus identification [6] [9].

Cardiac Computed Tomography (CT) and Cardiac Magnetic Resonance Imaging (MRI) are emerging alternatives for assessing the anatomy and function of the LA. Both modalities demonstrate comparable sensitivity and specificity to TEE. Cardiac CT shows high diagnostic accuracy for thrombus detection in the LA, particularly with delayed imaging. It effectively distinguishes between true thrombi and areas of low blood flow. However, it carries risks such as contrast nephropathy, especially in patients with chronic renal failure, and involves exposure to radiation [7] [9] [10].

Cardiac MRI offers high temporal resolution for visualizing LA size and function. However, its use is limited in patients with implanted cardiac devices, which restricts its applicability in certain populations [6] [11].

In summary, while TEE remains the primary imaging method for thrombus exclusion before cardioversion, CT and MRI provide valuable complementary options, each with specific advantages and limitations (**Figure 1**).

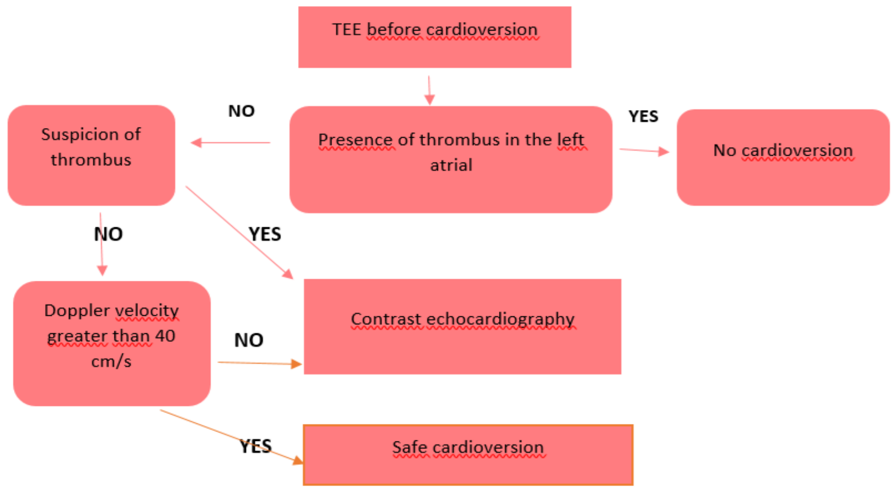

Figure 1. Algorithm for left atrial appendage assessment before cardioversion [6].

3.2. Rhythm Control

A recent study has shown that rhythm control at the index event of paroxysmal AF is much better at maintaining sinus rhythm and preventing progression to either persistent or permanent stages [12] [13]. The EAST-AFNET 4 study found that patients receiving early rhythm control had a 21% reduction in cardiovascular death, stroke (both ischemic and hemorrhagic), and hospitalizations due to worsening heart failure or acute coronary syndrome. Furthermore, a recent sub analysis indicated that the beneficial effects of early rhythm control were consistent in both symptomatic and asymptomatic patients [13]-[15].

3.2.1. Terms of the ECV

ECV is a common procedure for patients with AF aimed at restoring sinus rhythm, alleviating symptoms, and slowing disease progression. Immediate success rates for ECV range from 50% to 90% [6] [16]. The success of the procedure relies on several factors, including the waveform used, shock energy delivered, manual pressure applied, and electrode placement [16]. It is recommended that ECV be performed in a structured care setting, under sedation with intravenous Midazolam, Propofol, or Etomidate.

- **Waveform and Shock Energy**

High-energy biphasic shocks, exceeding 200 joules, may enhance the efficacy of restoring sinus rhythm in patients with recent AF. These high-energy shocks can also reduce the number of shocks needed, the risk of ventricular fibrillation (VF), and the requirement for antiarrhythmic drugs (AARs) post-procedure [16]-[18]. Escalating energy protocols (100-150-200 J) demonstrate similar cumulative success compared to high-energy protocols [17] [19] [20]. Conversely, some studies suggest that low-energy escalation shocks may be advantageous as they can lower the risk of skin burns, decrease patient discomfort, and minimize myocardial injury [16]-[18].

- **Manual Pressure**

The success of ECV is also influenced by the critical muscle mass that needs to be defibrillated and the capacity to deliver sufficient electrical current to the heart. This delivery is affected by shock energy and transthoracic impedance (TTI). When TTI is low, applying manual pressure to the defibrillator electrodes can help achieve adequate transmyocardial current, enhancing the likelihood of successful ECV. Conversely, a high TTI may lead to insufficient current for effective cardioversion [16]-[18] [21].

- **Position of the Electrodes**

The updated 2024 recommendations indicate that there is no significant difference in cardioversion success between anteroposterior and anterolateral electrode positions. Similarly, the Canadian Cardiovascular Society has found that electrode positioning does not impact cardioversion efficacy, although applying manual pressure may help in obese patients [16]-[18] [21]. However, some studies suggest that using anterolateral electrodes may reduce the number of shocks needed compared to the anteroposterior position. This is attributed to the anterolateral shock vector potentially stimulating a larger number of myocardial cells, while the anteroposterior vector primarily targets the LA. Therefore, anterolateral electrode placement is recommended for immediate cardioversion and transcutaneous pacing.

3.2.2. Orthogonal Electrical Cardioversion

In cases of paroxysmal AF that are refractory to the standard biphasic shock protocol (which involves 3 successive shocks of increasing energy or 2 to 3 initial shocks with a maximum energy of 200 joules), orthogonal electrical cardioversion (OECV) using low to medium energy (100 to 300 joules) can serve as an effective rescue strategy. The addition of OECV decreases the defibrillation threshold by providing sequential pulses to result in more consistent, homogeneous current density across a larger area [21]. OECV improves the defibrillation threshold by generating phase-locked pulses, providing a more effective as well as homogeneous current density. Changing the electrical vector between these subsequent shocks may also help in improving cardioversion success. In obese patients with chronic AF that is resistant to monophasic shocks and who exhibit high transthoracic impedance (TTI), high-energy double transthoracic shocks should be considered (**Table 1**).

Table 1. comparison between ECV and ECVO [2] [6].

	ECV	ECVO
Indication	-Immediate (hemodynamic instability) -Scheduled	-Paroxysmal AF or short-duration AF refractory to the standard biphasic shock protocol -Obese patients with chronic AF resistant to monophasic shocks -High ITT
Energy	High energy > 200 joules	Low or medium energy
Advantage	Quickly restores sinus rhythm	Reduces the defibrillation threshold

4. Complications of ECV

4.1. Thromboembolic Complications

ECV carries a significant risk of thromboembolic events. The incidence of such events post-procedure is notably higher in non-anticoagulated patients with AF, at 2%, compared to those receiving VKAs, where the rate is 0.33%. A recent Danish study highlighted that the rate of thromboembolic events within 30 days after cardioversion is low for patients on VKAs (0.28%) compared to those who were not anticoagulated (1.1%).

Another recent cohort study confirmed these findings, indicating that thromboembolic complications were more frequent when the INR was less than 2.5, as opposed to when it was 2.5 or higher. Notably, 78% of thromboembolic events occurred within 10 days of the procedure [22]. This evidence supports the recommendation to maintain appropriate anticoagulation for up to 4 weeks after cardioversion, or even longer, depending on the CHA_2DS_2-VA score.

The presence of pre-existing thrombi, transient atrial stunning that may occur after ECV, changes in mechanical atrial systolic function, left atrial diameter, and a prothrombotic state can all contribute to periprocedural thromboembolism.

Thromboembolic events can arise after successful cardioversion due to the migration of pre-existing thrombi into the LA, occurring in about 4% of cases in non-anticoagulated AF patients with a duration < 48 hours [23]. It is crucial to recognize that the absence of thrombus detected by TEE prior to cardioversion does not ensure the procedure's safety.

Restoration of sinus rhythm may lead to decreased blood flow velocity in the LA, increasing the risk of atrial stasis and promoting new thrombus formation, which can predispose patients to embolization [6] [23].

4.2. Rhythmic Complications

Bradycardia is a rare complication of ECV, occurring in approximately 0.9% of cases. It is typically benign but should be monitored, especially in elderly patients [24] [25], women, those with structural heart disease, a history of syncope, or diabetes. Interestingly, neither a slow ventricular rate nor pretreatment with antiarrhythmic or tricyclic antidepressants has been linked to an increased risk of asystole or Brady arrhythmia [24] [25].

Additionally, first-degree atrioventricular block has been associated with a higher risk of Brady arrhythmia. Bundle branch blocks and the duration of the QRS complex may also serve as important clinical markers for assessing the risk during ECV [25]-[27].

If bradycardia occurs after cardioversion, it can be managed with permanent pacemaker implantation, which has the added benefit of improving sinus node function and reducing the incidence of AF.

The incidence of Brady arrhythmias following the cardioversion of persistent AF ranges from 0.8% to 1.5%, indicating that a longer duration of AF may elevate the risk of bradycardia after the procedure [24].

Other rhythmic complications, although generally infrequent, can also occur after ECV. These include ventricular fibrillation, which may arise from inappropriate shock timing, as well as tachycardia such as atrial flutter and torsade de pointes.

4.3. Recurrence of AF

Recurrence of AF occurs in approximately 60% of cases within 3 to 6 months following cardioversion, with the highest incidence observed in the first 2 months. Several factors can predict this recurrence, including age, underlying cardiovascular disease, the duration of AF, inflammatory markers, and LA size [28] [29]. Recent studies indicate that the left atrial volume index (LAVI) is a more reliable predictor of AF recurrence after cardioversion than LA size alone [28] [29]. Specifically, a LAVI greater than 36 ml/m^2 is linked to an increased risk of AF recurrence following successful conversion [29].

As a result, measuring LAVI may be beneficial in identifying AF patients who are suitable candidates for cardioversion [28] [29]. However, despite the findings from these studies, the latest guidelines for the management of AF have not yet incorporated LAVI into the recommended echocardiographic assessments [28] [29].

- **Immediate Recurrences:**

Immediate relapses into persistent AF may be linked to hyper vulnerability in the immediate post-shock period, which can lead to atrial stunning. These recurrences can be mitigated through the use of Ibutilide, sodium channel antagonists, potentially by Sotalol and Amiodarone. Additionally, the risk of recurrence can be further reduced by combining Verapamil with class I or III AARs and by administering an immediate shock if needed [6] [30] [31].

- **Subacute Recurrences:**

These occur due to spatially no uniform reverse electrical remodeling, which increases the electrical instability of the atria. Such recurrences often happen within 1 to 2 weeks after the initial cardioversion.

- **Late Recurrences:**

Late recurrences can typically be managed with single AARs or additional cardioversions in patients at low risk of recurrence. For those with a higher risk of recurrence, catheter ablation may be considered as a more effective intervention [6] [32] (**Figure 2**).

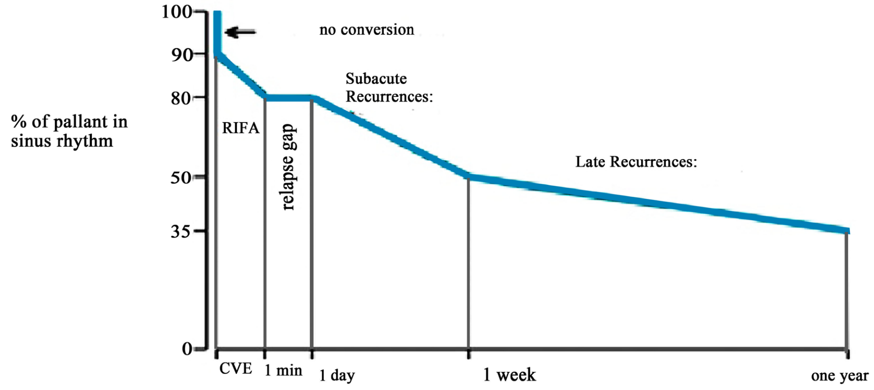

Figure 2. Recurrence after ECV of persistent AF [6].

5. Conclusions

Electrical cardioversion is an effective method for rhythm control in AF. Its effectiveness depends on several factors, including waveform, shock energy, manual pressure applied, and electrode placement. However, this procedure can lead to thromboembolic complications, emphasizing the importance of administering anticoagulants before and after the procedure to optimize safety.

ECV is a key intervention in the management of AF, aimed at restoring sinus rhythm and alleviating associated symptoms. This article highlights the various modalities of ECV, including the use of high-energy biphasic shocks and orthogonal cardioversion, which show promising results in terms of efficacy and safety.

Recent recommendations emphasize the importance of pre- and post-procedure anticoagulation to reduce the risk of thromboembolic complications, a critical issue given the high incidence of these events in non-anticoagulated patients. Despite the immediate success of ECV, with conversion rates reaching 90% in some cases, the risk of AF recurrence remains concerning, affecting about 60% of patients in the months following the procedure.

In summary, while ECV is an effective technique for rhythm control in atrial fibrillation, special attention must be paid to the management of potential complications and the evaluation of predictive factors for recurrence. Future research should focus on optimizing cardioversion protocols and identifying high-risk patients to improve clinical outcomes and reduce the burden associated with this condition.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviation

AAR:	Antiarrhythmics
AF:	Atrial Fibrillation
CT:	Computed Tomography
CVP:	Pharmacological Cardioversion
DOA:	Direct Oral Anticoagulants
ECV:	Electrical Cardioversion
ESC:	European Society of Cardiology
LA:	Left Atrium
LAVI:	Left Atrial Volume Index
MRI:	Magnetic Resonance Imaging
OECV:	Orthogonal Electrical Cardioversion
TTI:	Transthoracic Impedance
TTR:	Time Therapeutic Range
VKA:	Vitamin K Antagonists