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Fixed *vs.* incremental shock energy for atrial fibrillation: electrical cardioversion strategies in the emergency department

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Abstract

The optimal strategy for Electrical Cardioversion (ECV) in Atrial Fibrillation (AF) remains debated. We evaluated the impact of shock energy protocols on ECV outcomes in the Emergency Department (ED). This retrospective observational study included patients presenting with AF to the EDs in Trieste between January 2024 and April 2025. Patients undergoing ECV were classified according to initial shock energy: <200 J (incremental) or ≥200 J (fixed). Among 350 patients, overall ECV success was 92.6%, with 88.6% restoring sinus rhythm after the first shock. No significant difference in overall success was observed between incremental and fixed strategies (91.4% *vs.* 90.3%), although incremental energy achieved more first-shock conversions (88.1% *vs.* 77.4%). Magnesium sulphate premedication showed no significant association with ECV success (87.5% in patients who received magnesium *vs.* 93.2% in those who did not). Beta-blocker premedication was associated with lower success compared with no premedication (80% *vs.* 94.5%). Higher C-reactive protein levels were linked to failed cardioversion. These findings support individualized ECV strategies in the ED, with clinical judgment guiding energy selection and adjunctive therapies.

Key words: atrial fibrillation; electrical cardioversion; emergency department; magnesium sulphate.

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Introduction

Atrial fibrillation is the most common sustained arrhythmia worldwide and represents a growing public health challenge due to its rising prevalence and its strong association with stroke, heart failure, and mortality.[1,2] Its management in the Emergency Department (ED) is frequent, often urgent, and particularly relevant in patients presenting with significant symptoms or hemodynamic instability.[3] Synchronized Electrical Cardioversion (ECV) is an established and effective intervention for restoring sinus rhythm in AF, especially in unstable patients or when symptoms cannot be adequately controlled. Procedural success is affected by several factors, including thoracic impedance, patient habitus, sedation strategy, and the initial shock energy delivered.[4] The introduction of biphasic defibrillators has markedly improved ECV safety and effectiveness, allowing more efficient energy delivery and fewer complications than monophasic systems.[6,7] Still, the optimal initial shock energy remains debated.[8] Traditional incremental protocols (<200 J) have been widely used, but recent evidence supports high fixed-energy strategies (≥200 J), which may yield higher first-shock success without increasing adverse events.[9,10] The 2024 ESC Guidelines favour fixed-energy approaches, although the choice remains at the clinician's discretion based on patient characteristics.[8] Adjunctive therapies such as intravenous magnesium sulphate have gained attention. Multiple trials and meta-analyses suggest that magnesium may facilitate cardioversion and reduce ventricular rate without significant adverse effects, particularly in recent-onset AF).[11,12] More recent studies indicate that magnesium, alone or combined with antiarrhythmic agents, may provide modest but consistent improvements in cardioversion outcomes.[13-15] The aim of this study was to compare the effectiveness of fixed versus incremental initial shock strategies during ECV performed in the ED and to evaluate the effects of magnesium sulphate and other premedication regimens. Procedural characteristics and clinical predictors such as inflammatory markers and trigger factors were also examined.

Materials and Methods

Study design and population

This retrospective observational cohort study was conducted in two university-affiliated hospitals in Trieste, Italy. All patients presenting to the ED with AF between January 2024 and April 2025 were screened. Diagnoses were confirmed and coded according to ICD-9 criteria. Eligible patients were ≥18 years old and had either recent-onset AF or non-recent AF with adequate anticoagulation.

Adequate anticoagulation was defined as ongoing oral anticoagulant therapy (DOAC or VKA with therapeutic INR) or documented new-onset AF duration <24 hours; periprocedural anticoagulation was managed according to current ESC recommendations.

Study definitions

The incremental protocol was defined as an initial biphasic shock <200 J with escalation as needed, whereas the fixed protocol was defined as an initial biphasic shock ≥200 J. The primary outcome was first-shock success, defined as restoration of sinus rhythm after the first shock.

Data collection

Data were extracted from electronic medical records. Anonymized variables included demographic characteristics (age and sex), laboratory values (haemoglobin, WBC, CRP, potassium and magnesium), and clinical context variables such as infections, stimulant use (including alcohol, caffeine, opioids and other substances when documented), and ongoing stroke. Serum magnesium levels were not routinely measured and were available in a limited subset of patients. Procedural characteristics included shock energies, number of shocks and repeated attempts. Information on premedication (IV fluids, magnesium sulphate or rate-control drugs), antiarrhythmic drug therapy, and sedation (midazolam and/or fentanyl) was also collected. Outcomes included sinus rhythm restoration and adverse events.

Statistical analysis

Analyses were performed using Jamovi. Categorical variables were compared using Chi-square. Continuous variables were analysed using t-test or Mann–Whitney U-test depending on distribution. A p-value <0.05 was considered statistically significant.

Results

Study population

From January 2024 to April 2025, 1637 ED visits for AF were recorded (Table 1).

Of the 588 patients who underwent a cardioversion attempt, data regarding the type of treatment were available for 586 patients. Among them, 276 patients (47.1%) underwent Electrical Cardioversion (ECV) only, 133 patients (22.6%) Pharmacological Cardioversion (PCV) only, 65 patients (11.1%) received pharmacological cardioversion followed by electrical cardioversion, and 8 patients (1.4%) underwent electrical cardioversion followed by pharmacological cardioversion. One patient was treated with electrical cardioversion followed by pharmacological cardioversion and a subsequent additional attempt of electrical cardioversion. In addition, 103 patients (17.6%) achieved rhythm conversion after administration of adjunctive therapies other than hydration alone; these cases were classified as "supportive-therapy–assisted spontaneous cardioversions". For the purpose of this study, supportive-therapy–assisted cardioversion was defined as spontaneous conversion to sinus rhythm occurring after non-antiarrhythmic supportive interventions, without the administration of class I or class III antiarrhythmic drugs. Overall, at least one antiarrhythmic drug was administered in 207 patients, and at least one electrical shock was delivered in 350 patients.

Mean age was 71.4 years (95% CI: 70.5–72.4); 46.6% were female. ECV restored sinus rhythm in 92.6% of cases (324/350). Most required a single shock (94.4%). Failed ECV occurred in 7.4% of patients, often in those with structural heart disease or long-standing AF. Pharmacological cardioversion success was 59.9% overall (133 out of 207 treated), highest with flecainide (71.4%). (Figure 1, Table 2) Midazolam alone or combined with

Table 1. Descriptive characteristics of the study population.

Parameter	*n* measured	Mean (95% CI)	Median	Reference range
Sex				
Male	314 (53.4)	_	_	_
Female	274 (46.6)	_	_	_
Age	range 30-100	71.4 (70.5-72.4)	74 (65-80)	_
Male (years)	range 30-98	69.2 (68.0-70.4)	_	_
Female (years)	range 34-100	74.0 (72.8-75.3)	_	_
Labs				
Haemoglobin (g/dL)	555	13.98 (13.85-14.12)	14.1	13-17
White blood cells (/μL)	500	8317.2 (8025.1-8609.3)	7700	4000-11000
CPR (mg/L)	458	11.24 (8.53-13.95)	2,34	<5
Potassium (mEq/L)	559	4.00 (3.96-4.03)	4	3.5-5.1
Magnesium (mEq/L)	15	1.72 (1.53-1.92)	1.68	1.54-2.06
Sedation				
Midazolam only	148 (42.3%)	6.3	6 (5-7.5)	2-15
Fentanyl only	1 (0.3%)	_	_	_
Midazolam + Fentanyl	190 (54.3)	5.75	5 (4-7)	2-15
Antiarrhythmics	207			
Flecainide	140 (67.7)	_	_	_
Propaphenone	10 (4.8)	_	_	_
Amiodarone	57 (27.5)	_	_	_
Triggers				
Infections	33	_	_	_
Acute alcohol abuse	4	_	_	_
Caffeine	4	_	_	_
Thyroid dysfunction	6	_	_	_
Opioids	2	_	_	_

fentanyl was used. Successful ECV required lower midazolam doses (median 5 mg *vs*. 6 mg; p = 0.028). Female and older patients received lower sedative doses. Treatment with antiarrhythmics did not influence ECV success or shock requirements. In addition to electrical and pharmacological cardioversion, 103 patients achieved restoration of sinus rhythm following supportive therapy alone (Table 3).

Supportive measures included intravenous fluid resuscitation aimed at correcting dehydration or hypovolemia, correction of electrolyte imbalances – particularly potassium and magnesium– supplemental oxygen therapy when clinically indicated, and procedural sedation. No antiarrhythmic agents with a known direct effect on atrial electrophysiology were used in this subgroup.

Most premedications – including fluids, potassium, digoxin, and diltiazem – were not associated with outcome differences. (Table 4) Beta-blockers were associated with lower ECV success (94.5% no beta-blocker vs. 80% metoprolol vs. 73.7% bisoprolol; p = 0.002). Documented triggers included infections (n=33), alcohol (n=4), caffeine (n=4), thyroid dysfunction (n=6), and opioid use (n=2). CRP was significantly higher in failed ECV (13.64 *vs*. 7.92 mg/L; p = 0.011).

Shock energy and protocol comparison

Success rates were similar between strategies (91.4% incremental vs. 90.3% fixed; Figures 2 and 3, Table 5). However, first-shock success was higher with incremental energy (88.1% *vs*. 77.4%), while second-shock use was more common with fixed energy (22.6% *vs*. 8.2%) (p=0.026). Data about shock energy were not available in 7 patient charts.

Magnesium sulphate

Of 350 ECV patients, 32 were administered magnesium sulphate. Success was 87.5% with magnesium *vs*. 93.2% without (no significant difference between the groups). Magnesium did not affect the number of shocks required.

Discussion

This study analysed ECV practice in the ED, focusing on energy strategies, sedation, and premedication. ECV success exceeded 90%, typically with a single shock. No significant difference was observed in cardioversion outcomes between fixed and escalating energy protocols. While the 2024 ESC guidelines suggest favouring fixed energy protocols over escalating ones, they do not provide specific numerical recommendations.

One trial evaluating biphasic energy protocols (*e.g.*, escalating: 100 J, 150 J, 200 J *vs*. fixed: 200 J, 200 J, 200 J) demonstrated higher first-shock success in overweight patients (BMI > 25 kg/m²) with fixed protocols, but no difference in patients with normal BMI. Overall procedural success and the number of shocks required did not differ significantly between groups.[10]

Our findings are consistent with these observations. The lack of superior outcomes with fixed energy protocols may reflect the real-world decision-making process. In our study, more shocks were required in patients treated with fixed protocols, potentially

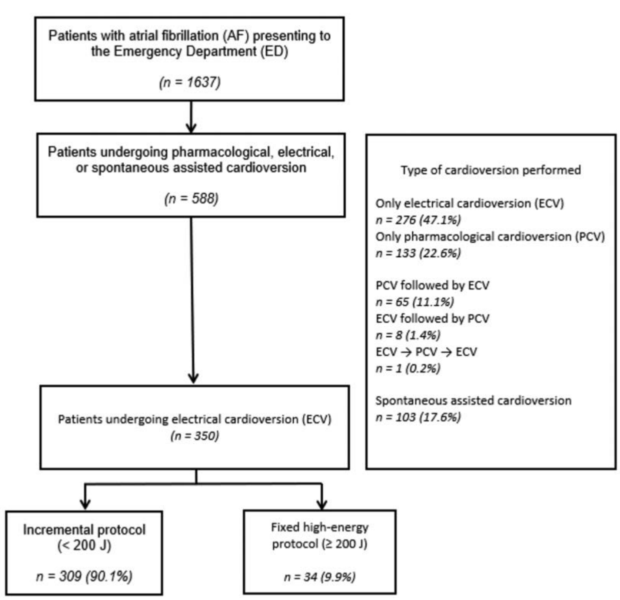

Figure 1. Flowchart of electrical cardioversion in patients with atrial fibrillation presenting to the emergency department.

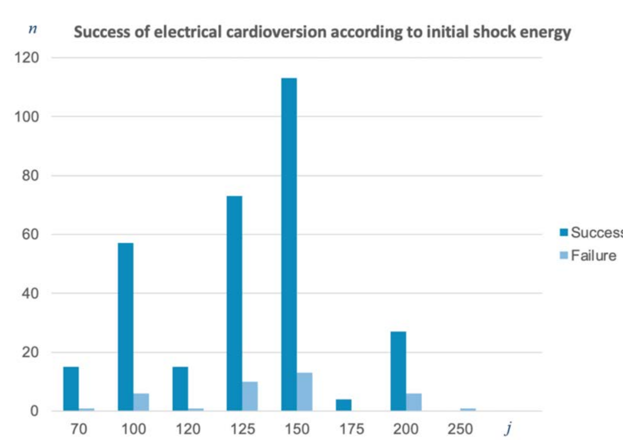

Figure 2. Success of electrical cardioversion according to initial shock energy.

Table 2. Antiarrhythmic drugs and success of pharmacological cardioversion.

Antiarrhythmic drug	Patients treated	Successful (%)	Unsuccessful (%)
Flecainide	140	100 (71.4)	40 (28.6)
Propafenone	57	21 (36.8)	36 (63.2)
Amiodarone	10	3 (30)	7 (70)
Total	207	124 (59.9)	83 (40.1)

Table 3. Non-antiarrhythmic supportive interventions in patients who achieved spontaneous assisted cardioversion.

Pharmacological supportive intervention	Number treated	% out of 103 patients
Beta-blocker	48	46.6
Metoprolol	26	25.2
Bisoprolol	17	3.9
Metoprolol + bisoprolol	4	1.0
Nebivolol	1	1.0
Potassium	41	39.8
With beta-blocker	8	7.8
Without beta-blocker	33	32
Magnesium Sulphate	21	20.4
With potassium	6	5.8
With beta-blocker	2	1.9
Fluid resuscitation (accompanied to other pharmacological intervention)	74	71.8
Saline solution (NaCl 0.9%)	56	54.4
Ringer acetate	8	7.8
Saline (NaCl 0.9%) + Ringer acetate	10	9.7
Digoxin	3	2.9
Diltiazem	2	1.9
Procedural sedation (midazolam + fentanyl)	2	1.9
Others	3	2.9

Table 4. Non-antiarrhythmic supportive interventions before an attempted either electrical cardioversion or pharmacological cardioversion.

Pharmacological supportive intervention	Number treated	% out of 483 patients
Beta-blocker	48	9.9
Metoprolol	26	5.3
Bisoprolol	17	3.5
Metoprolol + bisoprolol	4	0.8
Sotalol	1	0.2
Potassium	41	2
With beta-blocker	8	1.7
Without beta-blocker	33	6.8
Magnesium Sulphate	21	4.3
With potassium	6	1.24
With beta-blocker	2	0.4
Fluid resuscitation (accompanied to other pharmacological intervention)	74	15.3
Saline solution (NaCl 0.9%)	56	11.6
Ringer acetate	8	1.7
Glucose water 5% or 10%	35	7.2
Saline (NaCl 0.9%) + Ringer acetate	10	2.1
Digoxin	3	0.6
Adenosine (for differential diagnosis purpose)	15	3.1
Diltiazem	2	0.4
Furosemide	17	3.5
Benzodiazepines	2	0.4
Acetylsalicylic acid	4	0.8
Paracetamol	4	0.8
Oxygen	12	2.5
Others	3	0.6

Table 5. Success and failure rates of electrical cardioversion based on the number of shocks delivered.

	Number	Min (J)	Max (J)	Median (J)	25° (J)	75° (J)	Return sinus rhythm (%)	Failure of cardioversion (%)
Energy 1st shock	342	70	250	125	120	150	88,3	11,7
Energy 2nd shock	40	100	250	175	150	200	40	60
Energy 3rd shock	10	150	200	200 J	175	200	20	80

because it was more often applied in cases with anticipated failure – such as patients who were clinically unstable, sub optimally prepared, or presenting with long-standing AF. In contrast, in patients who were clinically optimized (*e.g*., younger, hemodynamically stable, with recent-onset arrhythmia), physicians seemed prone to opt for lower initial energy settings and escalating protocols. This context-sensitive choice may have biased the relationship between shock protocol and outcome, masking potential benefits of fixed high-energy strategies.

Additionally, patients requiring three or more shocks often had known persistent AF or underlying structural heart disease – both factors known to reduce the likelihood of successful cardioversion. This underscores the importance of a tailored clinical evaluation, including history of prior arrhythmias and echocardiographic assessment, to guide therapeutic decisions.

Sedation was tailored to patient characteristics: midazolam was frequently combined with fentanyl, which allowed for dose reduction. Females and older patients received lower doses of both sedatives, consistent with pharmacological guidelines.[10]

In our population, lower midazolam doses were associated with higher cardioversion success. One likely explanation is that patients with lower body weight, who require less sedation, tend to have a higher probability of successful cardioversion. Although body weight was not systematically recorded, this hypothesis is consistent with known clinical correlations.

However, additional factors may contribute to this association. Patients under the influence of stimulants, conditions observed in this study, required higher doses of midazolam to achieve adequate sedation and also demonstrated lower success rates, suggesting that an elevated adrenergic state may interfere with rhythm restoration. Moreover, patients requiring multiple shocks, indicative of less effective cardioversion, needed deeper and repeated sedation, resulting in higher total midazolam doses. These overlapping situations may explain the inverse relationship observed between midazolam dose and first-shock success.

The pre-treatment use of antiarrhythmics such as flecainide or amiodarone did not significantly alter ECV outcomes, confirming findings from previous randomized trials.[16] Magnesium sulphate also showed no significant impact on procedural success, possibly due to the limited sample size of patients included.

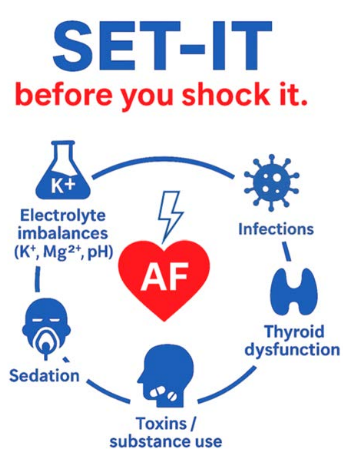

Figure 3. Factors for patient optimization prior to electric shock in hemodynamically stable patients. SET-IT: optimal sedation (eg. midazolam + fentanyl); correction of electrolyte (K+, Mg2+ and pH) and Hb imbalances; exclusion of thyroid dysfunctions; exclusion and management of infections; consider toxin and substance abuse (eg. caffeine, alcohol, cocaine and opioids, ketamine, etc.). Schematic representation created by the authors.

Spontaneous cardioversion occurred in approximately 14.5% of all patients and was often preceded by fluid resuscitation or electrolyte correction. Hypokalaemia correction, in particular, appeared to support rhythm conversion. These findings highlight the potential value of overall metabolic optimization prior to ECV. Several clinical triggers potentially contributing to the onset or persistence of atrial fibrillation were identified in this study, including infections, substance use – such as alcohol, caffeine and opioids – and thyroid dysfunction. These findings are in line with current literature,[17] which recognizes acute infections as well-established triggers of AF due to systemic inflammation and its associated electrical and structural remodelling at the atrial level. Supporting this, patients who did not achieve sinus rhythm after ECV had higher levels of C-reactive protein, suggesting an active inflammatory state may reduce the likelihood of successful cardioversion. This aligns with the hypothesis, widely supported in the literature, that inflammation can destabilize atrial myocardium and impair rhythm control outcomes.

Although thyroid dysfunction was documented in only few cases, its actual prevalence in the cohort may have been underestimated, as thyroid hormone testing is not routinely performed in the emergency department. Previous studies have reported a prevalence of thyroid disease of approximately 10% in patients with AF, indicating the need for greater diagnostic attention to this reversible condition.

Stimulant use, including alcohol and caffeine, has also been associated with increased AF risk in several studies, although the clinical impact of these factors may vary. In this cohort, stimulant use did not significantly affect laboratory markers or procedural parameters of ECV. However, patients exposed to stimulants required higher doses of midazolam for adequate sedation. This subgroup was also younger on average, which could partly explain the increased sedative requirements, but it is also plausible that a heightened adrenergic state in these individuals contributed both to the need for deeper sedation and to a potentially reduced probability of successful rhythm restoration. While stimulant exposure was not directly linked to poorer outcomes in this study, its effect on sedation requirements and autonomic tone may represent an important area for further investigation.

Overall, clinical decisions were influenced by patient-specific factors rather than protocol-driven approaches. The sample size, while adequate overall, was limited in certain subgroups, such as those treated with fixed-energy protocols or who received intravenous magnesium. Further studies are needed to refine best practices for ECV in the ED setting.

Conclusions

In this retrospective cohort, Electrical Cardioversion (ECV) for atrial fibrillation proved highly effective, with no significant difference in outcomes between fixed and escalating energy protocols. These findings suggest that initial energy selection should be guided by clinical judgement rather than rigid adherence to one strategy.

Key factors associated with ECV success included tailored sedation – particularly weight- and age-adjusted dosing – and the absence of overt systemic inflammation. Bedside echocardiography and a focused clinical history (including prior arrhythmia management and comorbid structural heart disease) were considered essential to procedural planning.

Although magnesium sulphate premedication did not significantly improve cardioversion success overall, it may still be considered in patients with coexisting hypokalaemia or anticipated procedural complexity, given its favourable safety profile. Its limited use in the study population may have reduced the statistical power to detect a significant effect. Correction of electrolyte imbalances prior to ECV – especially hypokalaemia and hypomagnesemia – was associated with spontaneous or facilitated rhythm conversion in selected cases.

Antiarrhythmic pre-treatment did not enhance the efficacy of subsequent ECV, aligning with existing evidence.

In conclusion, effective management of atrial fibrillation in the emergency setting requires a personalized approach that respects current guideline principles while adapting to each patient's clinical condition, arrhythmic profile, and metabolic state.

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All authors approved the final manuscript.

Conflict of interest: the authors declare no potential conflict of interest, and all authors confirm accuracy.

Ethics approval: this retrospective observational study was conducted using pseudonymized data extracted from an institutional hospital registry and originally collected for routine clinical care and subsequently analysed for clinical audit and quality improvement purposes.
According to Italian data protection regulations, retrospective studies based on pseudonymized data collected for clinical purposes do not require informed consent. The study was conducted in accordance with the principles of the Declaration of Helsinki (1964, revised 2013).

Informed consent: informed consent was not required due to the retrospective design and the use of pseudonymized data.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

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