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Dual vs Single Cardioversion of Atrial Fibrillation in Patients With Obesity
A Randomized Clinical Trial

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IMPORTANCE Atrial fibrillation and obesity are common, and both are increasing in prevalence. Obesity is associated with failure of cardioversion of atrial fibrillation using a standard single set of defibrillator pads, even at high output.

OBJECTIVE To compare the efficacy and safety of dual direct-current cardioversion (DCCV) using 2 sets of pads, with each pair simultaneously delivering 200 J, with traditional single 200-J DCCV using 1 set of pads in patients with obesity and atrial fibrillation.

DESIGN, SETTING, AND PARTICIPANTS This was a prospective, investigator-initiated, patient-blinded, randomized clinical trial spanning 3 years from August 2020 to 2023. As a multicenter trial, the setting included 3 sites in Louisiana. Eligibility criteria included body mass index (BMI) of 35 or higher (calculated as weight in kilograms divided by height in meters squared), age 18 years or older, and planned nonemergent electrical cardioversion for atrial fibrillation. Patients who met inclusion criteria were randomized 1:1. Exclusions occurred due to spontaneous cardioversion, instability, thrombus, or BMI below threshold.

INTERVENTIONS Dual DCCV vs single DCCV.

MAIN OUTCOMES AND MEASURES Return to sinus rhythm, regardless of duration, immediately after the first cardioversion attempt of atrial fibrillation, adverse cardiovascular events, and chest discomfort after the procedure.

RESULTS Of 2079 sequential patients undergoing cardioversion, 276 met inclusion criteria and were approached for participation. Of these, 210 participants were randomized 1:1. After exclusions, 200 patients (median [IQR] age, 67.6 [60.1-72.4] years; 127 male [63.5%]) completed the study. The mean (SD) BMI was 41.2 (6.5). Cardioversion was successful more often with dual DCCV compared with single DCCV (97 of 99 patients [98%] vs 87 of 101 patients [86%]; $P = .002$). Dual cardioversion predicted success (odds ratio, 6.7; 95% CI, 3.3-13.6; $P = .01$). Patients in the single cardioversion cohort whose first attempt failed underwent dual cardioversion with all subsequent attempts (up to 3 total), all of which were successful: 12 of 14 after second cardioversion and 2 of 14 after third cardioversion. There was no difference in the rating of postprocedure chest discomfort (median in both groups = 0 of 10; $P = .40$). There were no cardiovascular complications.

CONCLUSIONS AND RELEVANCE In patients with obesity (BMI ≥35) undergoing electrical cardioversion for atrial fibrillation, dual DCCV results in greater cardioversion success compared with single DCCV, without any increase in complications or patient discomfort.

TRIAL REGISTRATION ClinicalTrials.gov Identifier: NCT04539158

Visual Abstract

Multimedia

Supplemental content

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The prevalence of atrial fibrillation (AF) and obesity continue to increase in parallel, posing a formidable impact on both the health care system and patients' quality of life. Atrial fibrillation stands as the most prevalent cardiac dysrhythmia, with projections of 6 to 16 million individuals in the US being affected by this condition by the year 2050.[1-5] Furthermore, it is projected that by 2030, approximately 1 in 2 adults will be classified as having obesity (BMI ≥30; calculated as weight in kilograms divided by height in meters squared), a condition that is associated with a 50% elevated risk of developing AF.[6-9] When a rhythm control strategy is adopted for patients with persistent atrial fibrillation, external direct-current cardioversion (DCCV) is the mainstay treatment for immediate restoration of sinus rhythm.

Studies have shown that even when maximum energy, biphasic waveform shocks are delivered, cardioversion using a single set of pads fails in 20% to 35% of patients with obesity, in contrast to the less than 10% failure rate in the general population.[10-16] This failure is often attributed to higher transthoracic impedance, atrial enlargement, and the dispersion of energy, which collectively lead to insufficient current density at the atrial myocardium.[17-20] Cardioversion failure may result in adverse patient outcomes related to multiple shocks and prolonged sedation duration, as well as a negative impact on quality of life and loss of cardiac benefit that would be expected from restoring sinus rhythm.[21,22] Patients with obesity may be particularly susceptible to such complications.

Dual DCCV, in contrast to the conventional approach using a single set of pads (single DCCV), uses 2 sets of defibrillator pads to administer simultaneous shocks, resulting in higher cumulative energy and current density delivered to the atrial myocardium.[23] Dual DCCV has historically been used as salvage therapy for patients with AF refractory to maximum energy single DCCV, with previous case reports and retrospective analyses demonstrating this strategy to be potentially more effective and safe.[18,24-30] In response to the notably elevated rate of cardioversion failure among patients with obesity, this study sought to evaluate the comparative effectiveness of dual DCCV vs single DCCV as an initial therapeutic approach for managing AF in this specific patient population.

Key Points

Question Is dual direct-current cardioversion a more effective cardioversion strategy than single direct-current cardioversion in patients with atrial fibrillation and obesity?

Findings In this multicenter, patient-blinded, randomized clinical trial of 200 patients with obesity (body mass index ≥35) and atrial fibrillation, dual direct-current cardioversion was associated with a significantly higher likelihood of cardioversion success (98%) compared with standard single direct-current cardioversion (86%), without increased risk of adverse events.

Meaning Dual direct-current cardioversion results in a higher rate of success of cardioverting atrial fibrillation in patients with obesity compared with conventional single direct-current cardioversion.

Methods

Trial Design and Oversight

This multicenter, parallel-group, single-blinded, randomized clinical trial was designed to investigate whether dual DCCV is superior to single DCCV as an initial treatment strategy for cardioversion of AF in patients with obesity. The study was approved by the Ochsner Health institutional review board and was performed in accordance with the principles of the Declaration of Helsinki. The trial protocol and statistical analysis plan are available in Supplement 1 and Supplement 2, respectively. The trial followed the Consolidated Standards of Reporting Trials (CONSORT) reporting guidelines.

Patient Population

Between August 2020 and August 2023, patients scheduled for elective external cardioversion of AF in 3 centers (Ochsner Medical Center, New Orleans, Louisiana; Ochsner Medical Center–West Bank, Gretna, Louisiana; and Louisiana Health Science Center–Shreveport, Shreveport, Louisiana) were screened. There were considerable differences in the number of patients recruited from the 3 sites. Inclusion criteria were age 18 years or older, body mass index (BMI) of 35 or higher (calculated as weight in kilograms divided by height in meters squared), and therapeutic anticoagulation. Exclusion criteria included emergent cardioversion, pregnancy, and/or incarceration. All clinical trial data were entered directly from the participating sites into a web-based secure REDCap database (Vanderbilt University).[31] Patients' self-identified race and ethnicity were codified as Black vs non-Black and Hispanic vs non-Hispanic. The patients gave written informed consent. Patient data in the database were deidentified.

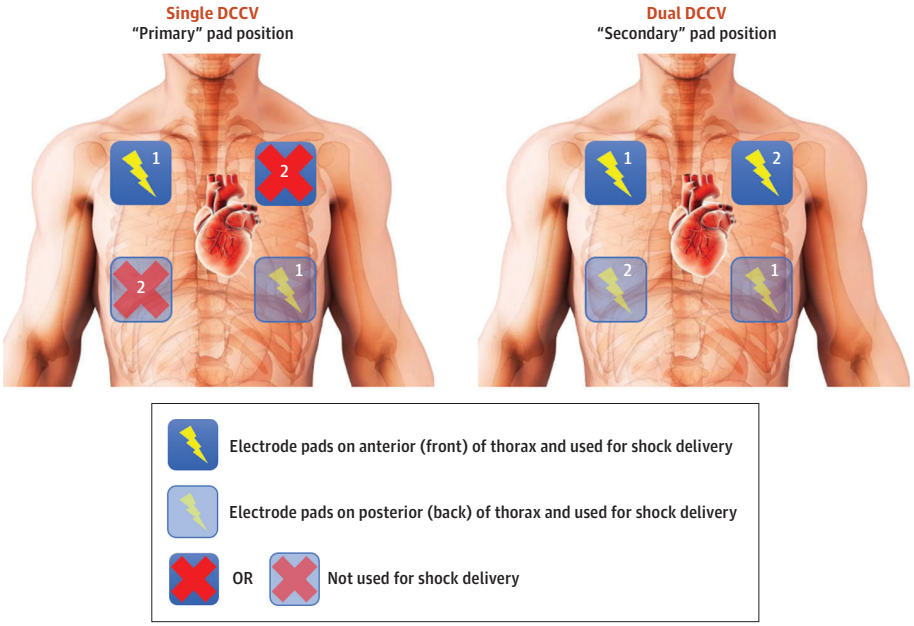
Following patients' acceptance of involvement in the trial, the REDCap randomization tool was used to randomize participants in a 1:1 ratio into single-DCCV vs dual-DCCV cohorts. Enrollment and randomization were performed by a clinical research coordinator. Patients were blinded to treatment assignment. No important changes to the methods were made after trial commencement.

End Points

The primary end point was successful cardioversion to sinus rhythm, irrespective of duration (defined as ≥1 beat of sinus rhythm), after the first DCCV attempt, assessed immediately after shock delivery. As the trial focused on evaluating the immediate effectiveness of each cardioversion modality, we did not monitor the occurrence or timing of AF recurrence after successful cardioversion. These details pertain to the durability of sinus rhythm, which is influenced by several factors including atrial myopathy severity, duration of AF, and other acute/chronic medical conditions known to exacerbate AF recurrence.[32-34]

Secondary safety outcomes included postcardioversion tachyarrhythmias (excluding early recurrence of atrial fibrillation), bradyarrhythmias, chest discomfort (reported by the

Figure 1. Defibrillation Pad Placement and Shock Vectors



This figure demonstrates the orientation of the 4 pads and indicates the set(s) of defibrillation pads used for cardioversion in the single and dual direct-current cardioversion (DCCV) cohorts, respectively. The numbers on the pads correspond to the pad pairs.

patient in recovery before discharge using a visual analog scale of 0-10), stroke, myocardial infarction, and death.

Cardioversion Procedure

The participants were blinded to randomized treatment assignment. Deep sedation primarily involved the administration of propofol, sometimes supplemented by midazolam and/or fentanyl. Transesophageal echocardiography (TEE) was performed before DCCV if indicated to exclude the presence of intracardiac thrombus. To ensure appropriate electrode contact, body hair was removed with clippers, and the skin was confirmed to be clean and dry. Two sets of electrode patches were placed on all patients (**Figure 1** and eFigure in Supplement 3), regardless of treatment assignment. Both electrode pairs were in the anterior-posterior position, with slight modification to accommodate 2 sets of pads. The primary set included 1 patch inferior to the right clavicle and at the right sternal border, with its paired patch placed on the posterior chest wall slightly left of midline. For the secondary set of pads, we positioned the anterior patch inferior to the left clavicle and adjacent to the left sternal border, with its paired patch placed on the posterior chest wall slightly rightward of midline. This pad orientation created 2 different shock vectors encompassing the cardiac structures in a crisscrossing fashion.

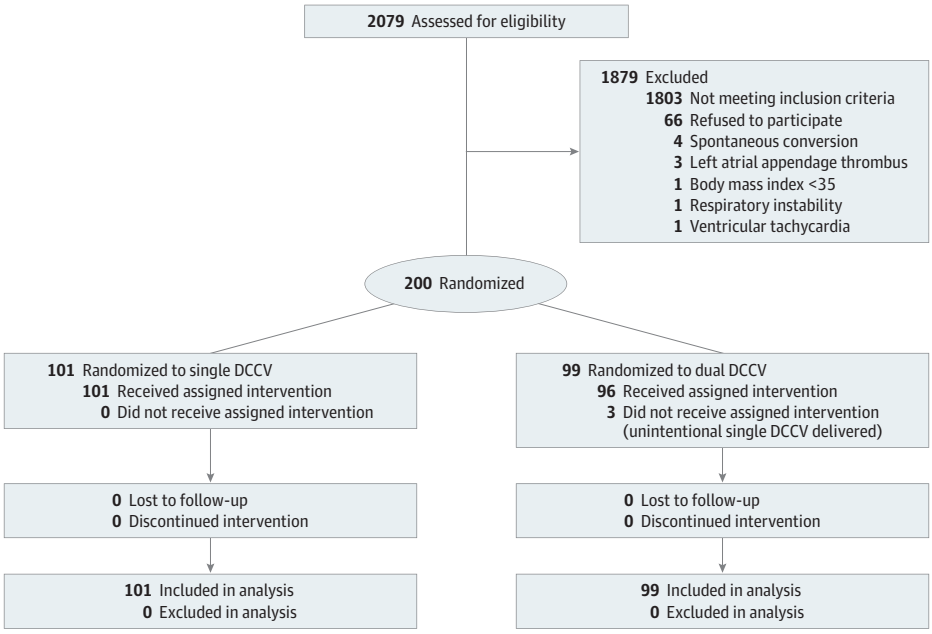
Biphasic cardioversion shocks were delivered via ZOLL R Series external cardioverter-defibrillator units (ZOLL Medical), with 1 set of electrodes attached to each defibrillator unit. The single-DCCV group received a single QRS-synchronous 200-J shock from the primary electrode pair. The dual-DCCV group received simultaneous QRS-synchronized shocks using both the primary and secondary electrode pairs, totaling 400 J. In dual DCCV, the defibrillator units' shock buttons were pressed simultaneously, resulting in delivery of shocks from both units synchronized to the same QRS complex. This procedure is demonstrated in the **Video**. In both groups, failure of the first shock could be followed by a maximum of 2 additional DCCV attempts, or fewer if deemed medically appropriate by the treating physician, all using the dual-DCCV technique. Treating physicians did not apply manual pressure to the pads and did not time shocks to the respiratory cycle.

For all subsequent cardioversion attempts in patients whose initial cardioversion failed, in both cohorts, the dual-DCCV strategy was used. This design was chosen for several reasons: (1) prior data have indicated suboptimal efficacy of single DCCV, even with multiple attempts, in patients with obesity,[12,13] (2) using dual DCCV in subsequent shocks for patients failing their initial single DCCV could provide insights into the performance of dual DCCV in a population with even more cardioversion-resistant AF (such as those with obesity and prior DCCV failure), (3) the design would lead to a higher number of dual-DCCV procedures being performed, thereby increasing the power to detect potential safety concerns, and (4) the recently updated "2023 American College of Cardiology/American Heart Association/American College of Clinical Pharmacy/Heart Rhythm Society Guideline for the Diagnosis and Management of Atrial Fibrillation," recommends modifying subsequent shocks (eg, changing shock vector or increasing energy), consistent with previous recommendations, after cardioversion failure—and both of these goals are achieved with the dual-DCCV strategy.[32,35]

Statistical Methods

All analyses were performed using SAS/STAT, version 15.2 (SAS Institute) and SPSS, version 27 (SPSS Inc). For all tests, a 2-sided *P* value < .05 was considered statistically significant.

Figure 2. Consolidated Standards of Reporting Trials Flow Diagram



DCCV indicates direct-current cardioversion.

The sample size was determined using assumptions based on prior published studies.[14,18,28] Using an expected efficacy of 75% for single DCCV and 90% for dual DCCV, we calculated that enrolling 200 patients and randomizing 1:1 would result in 80% power at a 2-sided α = .05. The statistical analysis was performed using the principle of intention to treat.

Binary data are described as counts and frequencies, and continuous data are described as mean (SD) or median (IQR). Baseline characteristics were compared using χ^2 or Fisher exact tests for categorical variables, as appropriate, and continuous variables were compared using unpaired *t* tests for normally distributed variables or the Mann-Whitney *U* test when the data were not normally distributed. The normality of variables' distributions was assessed using histograms and Q-Q plots.

Univariable binary logistic regression was carried out for the end point of cardioversion success. Due to small effective sample sizes (ie, a low failure rate), we applied Firth penalization. Randomization balance of a set of prespecified covariates including BMI, age, sex, congestive heart failure, obstructive sleep apnea, left ventricular ejection fraction, left atrial volume index, diabetes, and antiarrhythmic drug use was evaluated. Multivariable analysis was precluded by low effective sample size (ie, few DCCV failures).

Results

Among 2079 total cardioversions performed in the study centers during the study period (August 2020-2023), 276 patients met inclusion criteria and were approached to participate in the study. Among these, 210 agreed to participate (**Figure 2**). Patients were recruited from the following 3 sites: Ochsner Medical Center, New Orleans, Louisiana (185 [92.5%]); Ochsner Medical Center-West Bank, Gretna, Louisiana (11 [5.5%]); and Louisiana Health Science Center-Shreveport, Shreveport, Louisiana (4 [2%]).

After randomization (n = 210), the controlled cardioversion procedures of 10 patients (5%; 4 patients [4%] were randomized to single DCCV, and 6 patients [6%] were randomized to dual DCCV) were canceled due to spontaneous conversion to sinus rhythm (n = 4), thrombus on TEE (n = 3), change in BMI to less than 35 (n = 1), respiratory instability (n = 1), or ventricular tachycardia resulting in emergent cardioversion (n = 1).

The first 200 patients (median [IQR] age, 67.6 [60.1-72.4] years; 73 female [36.5%]; 127 male 63.5%) who completed the study protocol composed the study population and were randomized 1:1 to single DCCV (101 [50.5%]) vs dual DCCV (99 [49.5%]). Participants self-identified with the following race and ethnicity categories: 39 Black (19.5%) 161 non-Black (80.5%), 1 Hispanic (0.5%), and 199 non-Hispanic (99.5%). The population's baseline characteristics are summarized in **Table 1**. Randomization resulted in well-balanced groups overall, although patients in the single-DCCV group tended to be older (median [IQR] age, 68.8 [61.8-74.1] years vs 66.6 [56.3-71.3] years; *P* = .003, Mann-Whitney *U* test). The distributions of sex, race, BMI, past medical history, medication use, left ventricular ejection fraction, and left atrial volume index were similar between the groups.

Due to technical difficulties, 3 patients (3%) randomized to receive dual DCCV actually received single DCCV. These 3 (all of whose cardioversions were successful) were included in the dual-DCCV group as dictated by the intention-to-treat principle. All patients were analyzed for the primary outcome.

Table 1. Baseline Characteristics of the Study Participants

Characteristics	Single DCCV (n = 101)	Dual DCCV (n = 99)
Age, median (IQR), y	68.6 (61.8-74.1)	66.6 (56.3-71.3)
Sex, No. (%)		
Female	37 (37)	36 (36)
Male	64 (63)	63 (64)
Race and ethnicity, No. (%)		
Black	15 (14.9)	24 (24.2)
Non-Black	86 (85.1)	75 (75.8)
Hispanic	0	1 (1)
Non-Hispanic	101 (100)	98 (99)
Body mass index, mean (SD)[a]	41.2 (7.0)	41.1 (6.0)
New-onset AF (<3 mo)	43 (42.6)	39 (39.4)
Prior DCCV	35 (34.7)	42 (42.4)
Medical history		
Congestive heart failure	48 (47.5)	44 (44.4)
Coronary artery disease	25 (25)	25 (25.3)
Obstructive sleep apnea	52 (51.5)	60 (60.6)
Diabetes	48 (47.5)	38 (38.4)
Chronic kidney disease	25 (24.8)	22 (22.2)
Peripheral arterial disease	14 (13.9)	13 (13.1)
Dyslipidemia	69 (68.3)	61 (61.6)
Hypertension	91 (90.1)	83 (83.8)
Echocardiographic, mean (SD)		
Left ventricular ejection fraction, %	52.3 (11.9)	51 (13.4)
Left atrial volume index, mL/m^2	47.7 (18.8)	47.8 (20.7)
Medications		
Antiarrhythmic drug use[b]	39 (38.6)	43 (43.4)
β-Blocker	85 (84.2)	85 (85.6)
Calcium channel blocker	33 (32.7)	22 (22.2)
ACE inhibitor/ARB	63 (62.4)	53 (53.5)
Sacubitril-valsartan	5 (5.0)	8 (8.1)
Mineralocorticoid-receptor antagonist	11 (10.9)	13 (13.1)
Diuretic	59 (58.4)	62 (62.6)
Antihyperlipidemic medication	64 (63.4)	67 (67.7)

Abbreviations: ACE, angiotensin-converting enzyme; AF, atrial fibrillation; ARB, angiotensin receptor blocker; DCCV, direct-current cardioversion.

[a] Calculated as weight in kilograms divided by height in meters squared.

[b] Antiarrhythmic drugs included flecainide, propafenone, dofetilide, sotalol, and amiodarone.

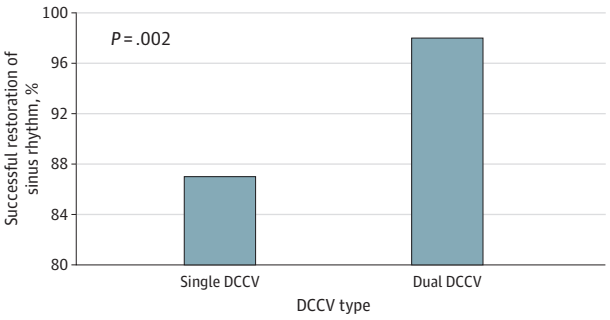
Primary Outcome

On the initial cardioversion attempt, success occurred more often in those randomized to the dual-DCCV group compared with the single-DCCV group (97 of 99 patients [98%] vs 87 of 101 patients [87%]; P = .002) (**Figure 3**). After successful cardioversion, patients were monitored in the cardioversion room during recovery from anesthesia, which usually lasted 10 to 15 minutes. No early recurrence of atrial fibrillation was observed during that time.

We further evaluated the association between DCCV modality and failure of cardioversion, using binary logistic regression (**Table 2**). On unadjusted analysis, the odds ratio (OR) of cardioversion success with dual DCCV compared with single DCCV was 6.5 (95% CI, 1.6-25.7; P = .008). After noticing some degree of intergroup imbalance, we performed logistic regression with inverse probability weighting and robust variance, including BMI, age, sex, congestive heart failure, obstructive sleep apnea, left ventricular ejection fraction, left atrial volume index, diabetes, and antiarrhythmic drug use.[36] In this analysis, dual DCCV had an adjusted OR for success of 6.7 (95% CI, 3.3-13.6; P = .01).

Due to significant disparity in the number of participants enrolled from the 3 centers, accounting for potential correlated responses by including center as a random effect resulted in a G matrix not being positive definite, as at 2 centers there were no unsuccessful cardioversions. Thus, we did not perform center-stratified analysis.

Figure 3. Efficacy of Cardioversion: Single Direct-Current Cardioversion (DCCV) vs Dual DCCV



Compared with single DCCV, cardioversion using the dual-DCCV strategy more often resulted in successful return to normal sinus rhythm.

Table 2. Binary Logistic Regression Examining the Association Between Direct Current Cardioversion (DCCV) Modality and Success of DCCV

	DCCV success, dual vs single	
Variable	OR (95% CI)	P value
Unadjusted	6.5 (1.6-25.7)	.008
Adjusted[a]	6.7 (3.3-13.6)	.01

Abbreviation: OR, odds ratio.

[a] Propensity score weighting with robust SE; covariates include body mass index, age, sex, congestive heart failure, obstructive sleep apnea, left ventricular ejection fraction, left atrial volume index, diabetes, and antiarrhythmic drug use.

Subsequent Cardioversions

Per protocol, after an unsuccessful single DCCV, each patient underwent up to 2 additional cardioversions, each using dual DCCV. Of the 14 patients with unsuccessful single-DCCV shocks, all 14 (100%) experienced successful cardioversion using subsequent dual DCCV: 12 of 14 patients (86%) after the second shock and 2 of 14 patients (14%) after the third shock. Among the 2 initial failures in the dual-DCCV group, 1 patient was successfully cardioverted by a second dual DCCV, and after 2 failed dual-DCCV attempts, the other patient underwent no further cardioversion on the day of the study. This patient received an amiodarone load and was successfully cardioverted using the dual-DCCV strategy 2 weeks later.

Safety

There was no difference in participants' rating of chest discomfort after the shock. The median in both groups was 0 of 10 (IQR, 0 and 0; P = .40). There were no adverse events reported in either group.

Discussion

This multicenter, patient-blinded, randomized clinical trial compared dual DCCV to single DCCV as an initial treatment of AF in patients with obesity who are undergoing nonemergent cardioversion. The primary outcome of cardioversion success occurred more often in the dual-DCCV group (ie, 2 sets of pads) compared with the single-DCCV group (ie, 1 set of pads): 98% vs 86%, respectively. Furthermore, all patients randomized to single DCCV whose initial cardioversion failed were successfully cardioverted on subsequent attempts using the dual-DCCV strategy. There were no significant adverse events, and there was no difference in postprocedure chest discomfort between the groups.

The correlation between increased body weight and higher risk of cardioversion failure has been well documented for over 2 decades,[10,11,13,37,38] starting with a comparison of internal vs external cardioversion efficacy that revealed body weight to be the only variable associated with DCCV outcomes.[10,11] Additional studies have corroborated these findings.[11,38,39] Although improvements in cardioversion techniques (notably the use of biphasic waveforms and maximal shock energy) have improved outcomes, still a sizable portion of patients with obesity require multiple cardioversions or are completely unable to attain sinus rhythm.

For successful cardioversion to occur, the current density at the level of the atrial myocardium must exceed the myocardial defibrillation threshold. It has been postulated that cardioversion failure in patients with obesity results from higher transthoracic impedance, larger interelectrode distance, and larger atrial size. Consequently, efforts have been directed toward exploring alternative strategies to overcome these obstacles, including manual pressure on the electrodes, alteration of electrode positioning, pretreatment with antiarrhythmic drugs, and increasing shock energy.[12,40-43]

In a study using increasing biphasic shock energy (50 J to 100 J to 150 J to 200 J) and anterior-posterior electrode positioning, the investigators found that application of pressure to the anterior electrode improved cardioversion success (96% vs 84%), reduced defibrillation threshold, and decreased both total shock energy and the required number of shocks.[43] In another study, cardioversion outcomes in patients with obesity (BMI ≥30) using various shock vectors (anteroposterior vs anteroapical) and pressure (handheld paddles vs adhesive patches) were evaluated in a 1:1:1:1 randomized clinical trial of 125 patients, with each cohort receiving escalating shock energy (100 J to 200J, with a third shock using crossover to patches or paddles using 200 J).[12] There was higher first or second shock success with paddles compared with patches (90% vs 68%) and a numerically higher success in patients in the crossover group using paddles when a third cardioversion attempt was required. A simultaneous observational substudy (n = 20) performed to assess manual pressure augmentation, timed to the end-expiratory phase of respiration, in patients with morbid obesity (BMI ≥35) and cardioversion-refractory AF (ie, failed up to 200 J with paddles and patches) showed 50% and 86% success in 200-J and 360-J shocks, respectively. There was no efficacy difference associated with electrode orientation, which is consistent with a recent metanalysis,[44] although conflicting evidence exists.[45] Lastly, antiarrhythmic drugs may be beneficial not only in maintaining sinus rhythm but also in their role as upstream facilitator of cardioversion success.[34,46]

The use of higher-energy shocks has produced encouraging results in both safety and effectiveness, making it a potential strategy to improve success in patients with obesity.[47-49] Energy selection in the biphasic era has been assessed using maximum-fixed (360 J to 360 J to 360 J) vs low-escalating (125 J to 150 J to 200 J) cardioversion protocols.[50] Successful cardioversion, defined as 1 minute of sinus rhythm, occurred more often in the maximum-fixed energy group compared with low-escalating group (88% vs 66%, respectively). Of note, the first attempt success rate of high-output 360-J shocks was only 75%, which the authors postulated may have resulted from 30% of the population having longstanding AF (duration >1 year). Importantly, there were no differences in safety end points or cardiac injury as measured by precardioversion and postcardioversion troponin levels.

In the late 1990s, dual DCCV was first used in the setting of atrial fibrillation to overcome cardioversion-refractory AF.[23] Since that time, several case reports and small series have indicated that dual DCCV may be a safe and effective strategy.[26,28] Currently, no consensus exists regarding the optimal cardioversion strategy in patients with obesity, highlighting the importance of defining an alternative strategy that is effective and safe.[21,32,35] As such, our findings may be clinically impactful. To our knowledge, this was the first prospective randomized clinical trial assessing dual DCCV. We postulate that the high efficacy seen in our study, compared with other studies including maximum energy shock trials, is the result of simultaneously combining 2 different means to improve shock success—maximizing energy output leading to higher current density, and using alternative shock vectors, potentially homogenizing and optimizing current delivery. The contemporary "2023 American College of Cardiology/American Heart Association/American College of Clinical Pharmacy/Heart Rhythm Society Guideline for the Diagnosis and Management of Atrial Fibrillation" marks the first occurrence of briefly addressing the challenges of electrical cardioversion in patients with obesity and the possible utility of dual DCCV. However, this document gives no specific guideline recommendations, given the scarcity of clinical data.[32]

Limitations

There are several important limitations to this study. First, the trial was single blinded (patient only). As such, the treating physician was aware of the treatment assignment, as they had to be present to press both shock buttons simultaneously. Second, the rhythm was analyzed by the treating physician after

delivery of the shocks, rather than being adjudicated by an independent blinded observer. Our centers universally use ZOLL R-series defibrillators (ZOLL Medical), which have maximum output 200 J. Thus, the potential efficacy of higher-output defibrillator units (eg, 360 J) could not be assessed. Only a single dual-DCCV pad orientation was trialed. The primary end point focused solely on the restoration of sinus rhythm after the first cardioversion attempt, irrespective of duration, and only the immediate post-DCCV period was monitored, precluding any conclusions about events occurring after the peri-DCCV period. Some baseline differences existed between the 2 groups (with only age reaching statistical significance), likely related to the relatively small sample size. Logistic regression with inverse probability weighting and robust variance were used to account for any imbalances between the randomized groups. Due to significant disparity in the number of patients enrolled at each of the 3 centers, site-specific analysis was not statistically feasible. Although participants were recruited from 3 separate sites, 1 site recruited the majority (92.5%). Finally, although the commonly used metric BMI was used to predict patients at a higher risk of cardioversion failure, other measures or analyses of body habitus, such as chest circumference, were not considered and may offer additional predictive capabilities.

Conclusions

In this randomized clinical trial, in patients with obesity (BMI ≥35) undergoing electrical cardioversion for atrial fibrillation, dual DCCV resulted in greater cardioversion success compared with conventional single DCCV, without any increase in complications or patient discomfort.

ARTICLE INFORMATION

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Concept and design: Aymond, Sanchez, Bernard, Khatib, Hiltbold, Morin.
Acquisition, analysis, or interpretation of data: Aymond, Castine, Khatib, Hiltbold, Polin, Rogers, Dominic, Velasco-Gonzalez, Morin.
Drafting of the manuscript: Aymond, Castine, Bernard, Morin.
Critical review of the manuscript for important intellectual content: All authors.
Statistical analysis: Velasco-Gonzalez, Morin.
Obtained funding: Morin.
Administrative, technical, or material support: Aymond, Castine, Khatib, Polin, Dominic.
Supervision: Castine, Khatib, Hiltbold, Rogers, Dominic, Morin.

Conflict of Interest Disclosures: Dr Castine reported receiving speaker fees from ZOLL Medical outside the submitted work. Dr Khatib reported receiving personal fees from Medtronic Inc, Biotronik Medical, and Abbott Medical during the conduct of the study. Dr Morin reported receiving speaker fees from ZOLL Medical outside the submitted work. No other disclosures were reported.

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REFERENCES

1. Wang TJ, Parise H, Levy D, et al. Obesity and the risk of new-onset atrial fibrillation. *JAMA*. 2004;292(20):2471-2477. doi:10.1001/jama.292.20.2471

2. Chugh SS, Havmoeller R, Narayanan K, et al. Worldwide epidemiology of atrial fibrillation: a Global Burden of Disease 2010 study. *Circulation*. 2014;129(8):837-847. doi:10.1161/CIRCULATIONAHA.113.005119

3. Miyasaka Y, Barnes ME, Gersh BJ, et al. Secular trends in incidence of atrial fibrillation in Olmsted County, Minnesota, 1980 to 2000, and implications on the projections for future prevalence. *Circulation*. 2006;114(2):119-125. doi:10.1161/CIRCULATIONAHA.105.595140

4. Go AS, Hylek EM, Phillips KA, et al. Prevalence of diagnosed atrial fibrillation in adults: national implications for rhythm management and stroke prevention: the Anticoagulation and Risk Factors in Atrial Fibrillation (ATRIA) study. *JAMA*. 2001;285(18):2370-2375. doi:10.1001/jama.285.18.2370

5. Rogers PA, Bernard ML, Madias C, Thihalolipavan S, Mark Estes NA III, Morin DP. Current evidence-based understanding of the epidemiology, prevention, and treatment of atrial fibrillation. *Curr Probl Cardiol*. 2018;43(6):241-283. doi:10.1016/j.cpcardiol.2017.06.001

6. Tsang TSM, Barnes ME, Miyasaka Y, et al. Obesity as a risk factor for the progression of paroxysmal to permanent atrial fibrillation: a longitudinal cohort study of 21 years. *Eur Heart J*. 2008;29(18):2227-2233. doi:10.1093/eurheartj/ehn324

7. Morin DP, Bernard ML, Madias C, Rogers PA, Thihalolipavan S, Estes NAM III. The State of the art: atrial fibrillation epidemiology, prevention, and treatment. *Mayo Clin Proc*. 2016;91(12):1778-1810. doi:10.1016/j.mayocp.2016.08.022

8. Ward ZJ, Bleich SN, Cradock AL, et al. Projected US state-level prevalence of adult obesity and severe obesity. *N Engl J Med*. 2019;381(25):2440-2450. doi:10.1056/NEJMsa1909301

9. Wanahita N, Messerli FH, Bangalore S, Gami AS, Somers VK, Steinberg JS. Atrial fibrillation and obesity–results of a meta-analysis. *Am Heart J*. 2008;155(2):310-315. doi:10.1016/j.ahj.2007.10.004

10. Lévy S, Lauribe P, Dolla E, et al. A randomized comparison of external and internal cardioversion of chronic atrial fibrillation. *Circulation*. 1992;86(5):1415-1420. doi:10.1161/01.CIR.86.5.1415

11. Frick M, Frykman V, Jensen-Urstad M, Östergren J, Rosenqvist M. Factors predicting success rate and recurrence of atrial fibrillation after first electrical cardioversion in patients with persistent atrial fibrillation. *Clin Cardiol*. 2001;24(3):238-244. doi:10.1002/clc.4960240313

12. Voskoboinik A, Moskovitch J, Plunkett G, et al. Cardioversion of atrial fibrillation in obese patients: results from the cardioversion-BMI randomized controlled trial. *J Cardiovasc Electrophysiol*. 2019;30(2):155-161. doi:10.1111/jce.13786

13. Glover BM, Walsh SJ, McCann CJ, et al. Biphasic energy selection for transthoracic cardioversion of atrial fibrillation: the BEST AF trial. *Heart*. 2008;94(7):884-887. doi:10.1136/hrt.2007.120782

14. Gurevitz OT, Ammash NM, Malouf JF, et al. Comparative efficacy of monophasic and biphasic waveforms for transthoracic cardioversion of atrial fibrillation and atrial flutter. *Am Heart J*. 2005;149(2):316-321. doi:10.1016/j.ahj.2004.07.007

15. Rho RW, Page RL. Biphasic vs monophasic shock waveform for conversion of atrial fibrillation. *Card Electrophysiol Rev*. 2003;7(3):290-291. doi:10.1023/B:CEPR.0000012398.01150.eb

16. Lavignasse D, Trendafilova E, Dimitrova E, Krasteva V. Cardioversion of atrial fibrillation and flutter: comparative study of pulsed vs low energy biphasic truncated exponential waveforms. *J Atr Fibrillation*. 2019;12(3):2172. doi:10.4022/jafib.2172

17. Kistler PM, Sanders P, Morton JB, Vohra JK, Kalman JM, Sparks PB. Effect of body mass index on defibrillation thresholds for internal cardioversion in patients with atrial fibrillation. *Am J Cardiol*. 2004;94(3):370-372. doi:10.1016/j.amjcard.2004.04.039

18. Gardner MW, Yadava M, Raitt MH, et al. Effectiveness of dual external direct current cardioversion for initial cardioversion in atrial fibrillation. *J Cardiovasc Electrophysiol*. 2019;30(9):1636-1643. doi:10.1111/jce.13994

19. Kerber RE, Grayzel J, Hoyt R, Marcus M, Kennedy J. Transthoracic resistance in human defibrillation. Influence of body weight, chest size, serial shocks, paddle size and paddle contact pressure. *Circulation*. 1981;63(3):676-682. doi:10.1161/01.CIR.63.3.676

20. Al Chekakie MO, Akar JG. Epicardial fat and atrial fibrillation: a review. *J Atr Fibrillation*. 2012;4(6):483. doi:10.4022/jafib.483

21. Gallagher MM, Guo XH, Poloniecki JD, Guan Yap Y, Ward D, Camm AJ. Initial energy setting, outcome and efficiency in direct current cardioversion of atrial fibrillation and flutter. *J Am Coll Cardiol*. 2001;38(5):1498-1504. doi:10.1016/S0735-1097(01)01540-6

22. Zhu W, Wu Z, Dong Y, Lip GYH, Liu C. Effectiveness of early rhythm control in improving clinical outcomes in patients with atrial fibrillation: a systematic review and meta-analysis. *BMC Med*. 2022;20(1):340. doi:10.1186/s12916-022-02545-4

23. Bleyer FL, Quattromani A, Caracciolo EA, Bjerregaard P. An aggressive approach in converting resistant atrial fibrillation. *Am Heart J*. 1996;132(6):1304-1306. doi:10.1016/S0002-8703(96)90487-1

24. Alaeddini J, Feng Z, Feghali G, Dufrene S, Davison NH, Abi-Samra FM. Repeated dual external direct cardioversions using 2 simultaneous 360-J shocks for refractory atrial fibrillation are safe and effective. *Pacing Clin Electrophysiol*. 2005;28(1):3-7. doi:10.1111/j.1540-8159.2005.09155.x

25. Marrouche NF, Bardy GH, Frielitz HJ, Günther J, Brachmann J. Quadruple pads approach for external cardioversion of atrial fibrillation. *Pacing Clin Electrophysiol*. 2001;24(9 Pt 1):1321-1324. doi:10.1046/j.1460-9592.2001.01321.x

26. Bjerregaard P, El-Shafei A, Janosik DL, Schiller L, Quattromani A. Double external direct-current shocks for refractory atrial fibrillation. *Am J Cardiol*. 1999;83(6):972-974, A10. doi:10.1016/S0002-9149(98)01048-0

27. Saliba W, Juratli N, Chung MK, et al. Higher energy synchronized external direct-current cardioversion for refractory atrial fibrillation. *J Am Coll Cardiol*. 1999;34(7):2031-2034. doi:10.1016/S0735-1097(99)00463-5

28. Kabukcu M, Demircioglu F, Yanik E, Minareci K, Ersel-Tüzüner F. Simultaneous double external DC shock technique for refractory atrial fibrillation in concomitant heart disease. *Jpn Heart J*. 2004;45(6):929-936. doi:10.1536/jhj.45.929

29. Konakanchi D, de Jongh Curry AL. Simultaneous double external DC shock techniques for atrial fibrillation: a simulation study. *Annu Int Conf IEEE Eng Med Biol Soc*. 2008;2008:1745-1748. doi:10.1109/IEMBS.2008.4649514

30. Chang AK, Lent GS, Grinberg D. Double-dose external cardioversion for refractory unstable atrial fibrillation in the ED. *Am J Emerg Med*. 2008;26(3):385.e1-385.e3. doi:10.1016/j.ajem.2007.07.024

31. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap)–a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-381. doi:10.1016/j.jbi.2008.08.010

32. Joglar JA, Chung MK, Armbruster AL, et al; Peer Review Committee Members. 2023 ACC/AHA/ACCP/HRS guideline for the diagnosis and management of atrial fibrillation: a report of the American College of Cardiology/American Heart Association joint committee on clinical practice guidelines. *Circulation*. 2024;149(1):e1-e156. doi:10.1161/CIR.0000000000001193

33. Pisters R, Nieuwlaat R, Prins MH, et al; Euro Heart Survey Investigators. 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):666-674. doi:10.1093/europace/eur406

34. Um KJ, McIntyre WF, Healey JS, et al. Pre- and post-treatment with amiodarone for elective electrical cardioversion of atrial fibrillation: a systematic review and meta-analysis. *Europace*. 2019;21(6):856-863. doi:10.1093/europace/euy310

35. January CT, Wann LS, Alpert JS, et al; American College of Cardiology/American Heart Association Task Force on Practice Guidelines. 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association task force on practice guidelines and the Heart Rhythm Society. *J Am Coll Cardiol*. 2014;64(21):e1-e76. doi:10.1016/j.jacc.2014.03.022

36. Zeng S, Li F, Wang R, Li F. Propensity score weighting for covariate adjustment in randomized clinical trials. *Stat Med*. 2021;40(4):842-858. doi:10.1002/sim.8805

37. Kerber RE. Transthoracic cardioversion of atrial fibrillation and flutter: standard techniques and new advances. *Am J Cardiol*. 1996;78(8A):22-26. doi:10.1016/S0002-9149(96)00562-0

38. Lip GYH, Merino JL, Banach M, et al. Impact of body mass index on outcomes in the edoxaban vs warfarin therapy groups in patients underwent cardioversion of atrial fibrillation (from ENSURE-AF). *Am J Cardiol*. 2019;123(4):592-597. doi:10.1016/j.amjcard.2018.11.019

39. Lacoste JL, Avalon JC, Ludhwani D, et al. Comparative effectiveness of direct current cardioversion in patients with atrial fibrillation and obesity with body mass index ≥50 kg/m^2. *Am J Cardiol*. 2023;203:234-239. doi:10.1016/j.amjcard.2023.06.121

40. Darrat Y, Leung S, Elayi L, et al. A stepwise external cardioversion protocol for atrial fibrillation to maximize acute success rate. *Europace*. 2023;25(3):828-834. doi:10.1093/europace/euad009

41. Stiell IG, Sivilotti MLA, Taljaard M, et al. Electrical vs pharmacological cardioversion for emergency department patients with acute atrial fibrillation (RAFF2): a partial factorial randomised trial. *Lancet*. 2020;395(10221):339-349. doi:10.1016/S0140-6736(19)32994-0

42. Cotter G, Blatt A, Kaluski E, et al. Conversion of recent onset paroxysmal atrial fibrillation to normal sinus rhythm—the effect of no treatment and high-dose amiodarone: a randomized, placebo-controlled study. *Eur Heart J*. 1999;20(24):1833-1842. doi:10.1053/euhj.1999.1747

43. Squara F, Elbaum C, Garret G, et al. Active compression vs standard anterior-posterior defibrillation for external cardioversion of atrial fibrillation: a prospective randomized study. *Heart Rhythm*. 2021;18(3):360-365. doi:10.1016/j.hrthm.2020.11.005

44. Vinter N, Holst-Hansen MZB, Johnsen SP, Lip GYH, Frost L, Trinquart L. Electrical energy by electrode placement for cardioversion of atrial fibrillation: a systematic review and meta-analysis. *Open Heart*. 2023;10(2):e002456. doi:10.1136/openhrt-2023-002456

45. Kirchhof P, Eckardt L, Loh P, et al. Anterior-posterior vs anterior-lateral electrode positions for external cardioversion of atrial fibrillation: a randomized trial. *Lancet*. 2002;360(9342):1275-1279. doi:10.1016/s0140-6736(02)11315-8

46. Crijns HJGM, Weijs B, Fairley AM, et al. Contemporary real-life cardioversion of atrial fibrillation: results from the multinational RHYTHM-AF study. *Int J Cardiol*. 2014;172(3):588-594. doi:10.1016/j.ijcard.2014.01.099

47. Joglar JA, Hamdan MH, Ramaswamy K, et al. Initial energy for elective external cardioversion of persistent atrial fibrillation. *Am J Cardiol*. 2000;86(3):348-350. doi:10.1016/S0002-9149(00)00932-2

48. Lobo R, White RD, Donato LJ, et al. Absence of significant myocardial injury following elective direct current cardioversion for atrial fibrillation. *Heart Rhythm O2*. 2022;4(3):180-186. doi:10.1016/j.hroo.2022.12.004

49. Gallagher MM, Yap YG, Padula M, Ward DE, Rowland E, Camm AJ. Arrhythmic complications of electrical cardioversion: relationship to shock energy. *Int J Cardiol*. 2008;123(3):307-312. doi:10.1016/j.ijcard.2006.12.014

50. Schmidt AS, Lauridsen KG, Torp P, Bach LF, Rickers H, Løfgren B. Maximum-fixed energy shocks for cardioverting atrial fibrillation. *Eur Heart J*. 2020;41(5):626-631. doi:10.1093/eurheartj/ehz585