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ORIGINAL RESEARCH ARTICLE

Anterior–Lateral Versus Anterior–Posterior Electrode Position for Cardioverting Atrial Fibrillation

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BACKGROUND: Smaller randomized studies have reported conflicting results regarding the optimal electrode position for cardioverting atrial fibrillation. However, anterior–posterior electrode positioning is widely used as a standard and believed to be superior to anterior–lateral electrode positioning. Therefore, we aimed to compare anterior–lateral and anterior–posterior electrode positioning for cardioverting atrial fibrillation in a multicenter randomized trial.

METHODS: In this multicenter, investigator-initiated, open-label trial, we randomly assigned patients with atrial fibrillation scheduled for elective cardioversion to either anterior–lateral or anterior–posterior electrode positioning. The primary outcome was the proportion of patients in sinus rhythm after the first shock. The secondary outcome was the proportion of patients in sinus rhythm after up to 4 shocks escalating to maximum energy. Safety outcomes were any cases of arrhythmia during or after cardioversion, skin redness, and patient-reported periprocedural pain.

RESULTS: We randomized 468 patients. The primary outcome occurred in 126 patients (54%) assigned to the anterior–lateral electrode position and in 77 patients (33%) assigned to the anterior–posterior electrode position (risk difference, 22 percentage points [95% CI, 13–30]; $P<0.001$). The number of patients in sinus rhythm after the final cardioversion shock was 216 (93%) assigned to anterior–lateral electrode positioning and 200 (85%) assigned to anterior–posterior electrode positioning (risk difference, 7 percentage points [95% CI, 2–12]). There were no significant differences between groups in any safety outcomes.

CONCLUSIONS: Anterior–lateral electrode positioning was more effective than anterior–posterior electrode positioning for biphasic cardioversion of atrial fibrillation. There were no significant differences in any safety outcome.

REGISTRATION: URL: https://www.clinicaltrials.gov; Unique identifier: NCT03817372.

Key Words: atrial fibrillation ■ electric countershock ■ electrodes

Direct current cardioversion is widely used for restoring sinus rhythm in patients with atrial fibrillation (AF).[1,2] Cardioversion is an everyday clinical procedure in emergency medicine, intensive care, and cardiology[3,4]; therefore, identifying the most effective method in which cardioversion is performed is important. Despite decades of routine use, the optimal electrode position for cardioverting AF is still unknown. Several smaller randomized studies have reported conflicting results.[4–15] Two studies using monophasic shocks found anterior–posterior electrode positioning to be more effective than anterior–lateral electrode

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Clinical Perspective

What Is New?

- Anterior–posterior electrode positioning is frequently used for electric cardioversion of atrial fibrillation, although the optimal electrode position is unknown.
- In this large, multicenter, randomized trial, we found anterior–lateral electrode positioning to be more effective when compared with anterior–posterior electrode positioning for cardioverting atrial fibrillation.
- The superiority of the anterior–lateral electrode position was statistically significant after both an initial low-energy shock and a final higher energy shock.

What Are the Clinical Implications?

- The findings are important for everyday clinical practice, as cardioversion is a common procedure.
- The study suggests a practice change in the standard approach to electrode positioning for cardioversion in favor of anterior–lateral electrode positioning.

Nonstandard Abbreviations and Acronyms

AF	atrial fibrillation
EPIC	Electrode Position In Cardioverting Atrial Fibrillation trial
RAFF2	Electrical Versus Pharmacological Cardioversion for Emergency Department Patients With Acute Atrial Fibrillation trial

positioning.[5,8] Accordingly, the anterior–posterior electrode position is widely used and suggested as optimal for cardioverting AF.[16,17] However, biphasic shocks are more effective and safer compared with monophasic shocks.[18–21] Therefore, findings from studies using monophasic shocks may not translate to current clinical practice that uses contemporary biphasic shocks. Two smaller studies used biphasic shocks and suggested that an anterior–lateral electrode position is more effective than an anterior–posterior electrode position,[13,15] whereas other studies have found no differences between the 2 positions.[4,10–12] Consequently, there is considerable controversy about the optimal electrode position for biphasic cardioversion. Two meta-analyses indicated that data supporting any advantage of either electrode position was insufficient, which warranted data from a well-powered and more decisive randomized study.[22,23] Therefore, we conducted the EPIC trial (Electrode Position In Cardioverting Atrial Fibrillation). In this multicenter randomized trial, we used contemporary biphasic shocks with energies escalating to maximum levels to compare anterior–lateral and anterior–posterior electrode positioning for cardioverting AF.

METHODS

The data, analytic methods, and study materials will not be made available to other researchers for the purposes of reproducing the results or replicating the procedure.

Trial Design and Participants

EPIC was a multicenter, investigator-initiated, randomized, open-label, blinded-outcome assessment trial. A list of participating study sites is provided in the Supplemental Material. The trial was approved by The Research Ethics Committee for the Central Denmark Region (registration no. 1-10-72-332-18). All patients provided written informed consent. Research assistants and health care providers from the participating study sites collected the data in collaboration with the study investigators. The study used REDCap (Research Electronic Data Capture) hosted at Aarhus University in Denmark for electronic screening, randomization, and data collection.[24] The investigators designed the trial, monitored and managed the data, and performed the statistical analyses. The trial is registered at ClinicalTrials.gov (URL: https://www.clinicaltrials.gov; Unique identifier: NCT03817372).

We enrolled adult patients (≥18 years of age) with AF who were scheduled for elective cardioversion. We excluded patients with arrhythmias other than AF; implantable devices (eg, pacemaker or implantable cardioverter defibrillator); hemodynamically unstable AF; untreated hyperthyroidism; known or suspected pregnancy; and those previously enrolled in the trial. Before cardioversion, patients were required to have received sufficient anticoagulation or a transesophageal echocardiogram documenting the absence of intracardiac thrombi.[2]

Randomization and Intervention

Patients were randomly assigned in a 1:1 ratio to receive cardioversion shocks using either anterior–lateral or anterior–posterior electrode positioning. Randomization was stratified according to the study site and with variable block sizes of 4, 6, or 8. To ensure proper concealment of assignments, randomization was performed by an external randomization service provided by the Clinical Trial Unit of the Department of Clinical Medicine at Aarhus University in Denmark.

After randomization and immediately before cardioversion, patients were prepared for cardioversion using either anterior–lateral or anterior–posterior electrode positioning. The electrode positions were defined in accordance with guideline recommendations (Figure 1).[25] Because of the nature of the study, the clinician who performed the cardioversion was not blinded to the electrode position used.

Synchronized shocks were delivered by a defibrillator using biphasic truncated exponential waveform (Lifepak 15 or 20 series; Stryker/Physio-Control Inc, Redmond, WA), through self-adhesive gel electrodes. Shocks were delivered until sinus rhythm was restored or up to a maximum of 4 shocks. We used escalating energy shocks of 100 J, 150 J, 200 J, and 360 J according to common clinical practice and guidelines.[25,26] Patients were anesthetized using 1 mg IV propofol per kilogram of body weight to a maximum dose of the height of the patient in centimeters minus 100 cm. Subsequent boluses of 20 mg were administered if required.[21]

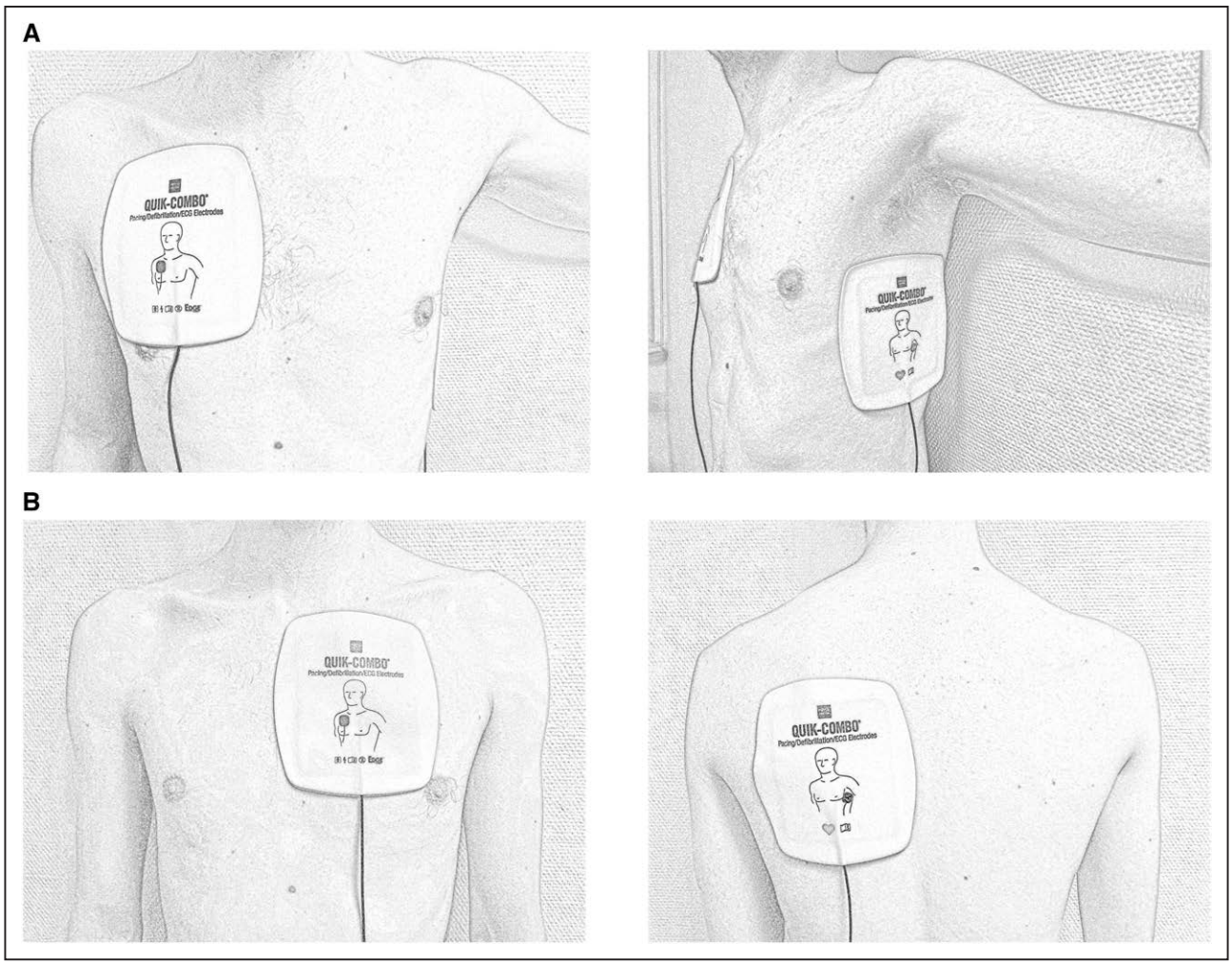

Figure 1. Electrode positions.
A, Anterior–lateral electrode position. The anterior electrode was placed in the right parasternal area in the mid-clavicular line. The lateral electrode was placed with the center of the electrode in the left mid-axillary line in level with the V6 ECG electrode.[25] **B**, Anterior–posterior electrode position. The anterior electrode was placed in the left parasternal area (ie, the precordium). The posterior electrode was placed in the left lower scapular region with the electrode edge left to the spinal column. The long axis of the electrodes was orientated in the craniocaudal direction for both electrode positions.

Outcomes

The primary outcome was the proportion of patients in sinus rhythm 1 minute after the first shock. The secondary outcome was the proportion of patients in sinus rhythm 1 minute after the final cardioversion shock, up to a maximum of 4 cardioversion shocks. Furthermore, we evaluated cardioversion efficacy at discharge 2 hours after cardioversion. Blinded assessment of the outcomes was performed centrally by an investigator through an electronic review of the cardioversion attempts using CODE-STAT 10 data review software (Stryker/Physio-Control Inc).

Safety outcomes included the number of patients with arrhythmic events (asystole, atrioventricular blocks, transient bradycardia, or ventricular arrhythmia) during or after cardioversion detected within 2 hours of continuous monitoring. A nurse assessed skin redness under the electrodes. The patients reported pain or discomfort on a numeric rating scale from 0 (no discomfort) to 10 (worst pain imaginable).

Statistical Analysis

We calculated the sample size on the basis of 2 previous randomized studies that compared anterior–lateral and anterior–posterior shocks using comparable low, escalating energy levels.[11,12] In these studies, the proportion of patients in sinus rhythm at 100 J was 66% to 72% for anterior–lateral and 51% to 60% for anterior–posterior electrode positioning. We therefore assumed an absolute difference in efficacy of 12.5%. A total study sample size of 468 patients (234 patients in each group) was needed to achieve a power of 80% in rejecting the null hypothesis (a difference in efficacy of <12.5%). The analyses of outcomes were performed on the intention-to-treat population. The proportions were compared using both risk difference and risk ratio with corresponding 95% CI. Effects of treatment were estimated by modified Poisson regression using generalized estimating equations with exchangeable working correlation structure to account for clustering by site.[27] Outcomes were analyzed across prespecified subgroups, and testing for interactions was performed (sex, body mass index,

first or >1 AF episode, and AF type). All analyses and graphics were performed using R statistical software (version 3.6.1).[28]

RESULTS

Trial Participants

In total, 468 patients underwent randomization at 3 sites in Denmark between February 19, 2019, and October 2, 2020 (sites listed in the Supplemental Material). Because 1 patient was accidentally randomized twice, the intention-to-treat population included 467 patients (Figure 2). Of those, 233 patients were randomized to anterior–lateral electrode positioning and 234 to anterior–posterior positioning. The clinical characteristics were well balanced between groups (Table; Tables S1 and S2). The baseline 12-lead ECGs obtained before randomization were carefully reviewed by 2 study investigators. The investigators disagreed with the enrolling clinicians in 8 of 467 patients (1.7%). These patients were judged to be in atrial flutter before randomization (2 assigned to anterior–lateral and 6 assigned to anterior–posterior shocks). These patients were included in the intention-to-treat population.

Intervention

All patients randomized to anterior–posterior electrode positioning received the assigned positioning. One patient randomized to anterior–lateral electrode positioning received anterior–posterior positioning. Two patients assigned to anterior–lateral electrode positioning underwent cardioversion using an anesthesia other than the prespecified propofol regimen (1 patient received midazolam; 1 patient received thiopental). No concomitant antiarrhythmic drugs were used immediately before or during cardioversion.

Outcomes

The primary outcome (ie, the number of patients in sinus rhythm 1 minute after the first shock) occurred in

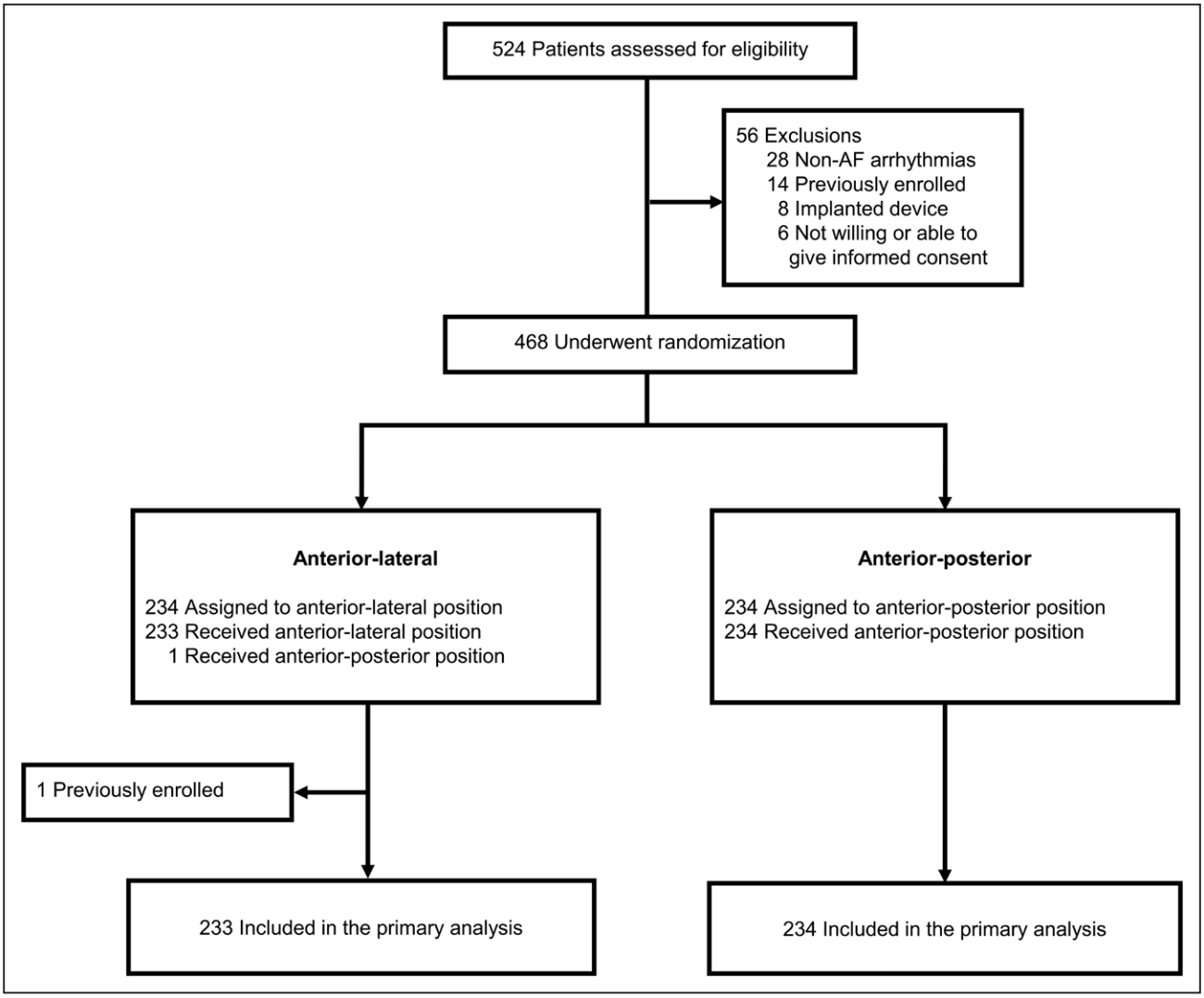

Figure 2. Participant flow chart illustrating screening, randomization, treatment, and analysis.
AF indicates atrial fibrillation.

Table. Clinical Characteristics of Patients at Baseline

Characteristics	Anterior–lateral (N=233)	Anterior–posterior (N=234)
Age, y*	68.7±9.5	68.9±9.3
Female sex, n (%)	77 (33)	76 (32)
Body mass index*†	28.8±5.8	28.9±5.4
Type of AF, n (%)		
Paroxysmal	42 (18)	51 (22)
Persistent	191 (82)	183 (78)
Duration of AF		
First AF episode, n (%)	100 (43)	116 (50)
Median months since AF diagnosis (IQR)	9 (1–60)	5 (1–46)
Median days of present AF episode (IQR)	27 (10–51)	30 (10–58)
Previous cardioversion, n (%)	104 (45)	91 (39)
Medical history, n (%)		
Arterial hypertension	149 (64)	151 (65)
Heart failure	67 (29)	54 (23)
Valvular heart disease	26 (11)	33 (14)
Ischemic heart disease	28 (12)	27 (12)
Diabetes	23 (10)	22 (9)
Previous stroke or transient ischemic attack	21 (9)	17 (7)
CHA_2DS_2-VASc score*‡	2.6±1.7	2.5±1.5
Medication use at baseline, n (%)§		
Amiodarone	39 (17)	30 (13)
Digoxin	42 (18)	32 (14)
Flecainide	4 (2)	2 (1)
β-blockers	194 (83)	179 (76)
ACE inhibitor or angiotensin II receptor blocker	123 (53)	114 (49)

There were no statistically significant differences between groups. Additional clinical characteristics and details on the definitions used are provided in Tables S1 and S2. Data were missing for 2 patients assigned to anterior–lateral positioning and for 2 patients assigned to anterior–posterior positioning. ACE indicates angiotensin-converting enzyme; AF, atrial fibrillation; and IQR, interquartile range.

*Data are mean ± SD.

†The body mass index is calculated as weight in kilograms divided by the square of the height in meters.

‡The CHA_2DS_2-VASc score is a measure of the risk of stroke in patients (congestive heart failure, hypertension, 65–74 years of age, diabetes, and vascular disease are assigned 1 point; previous stroke or transient ischemic attack, and ≥75 years of age are assigned 2 points).

§Additional characteristics on medications and dosages are provided in Table S2. An extended version of the Table is provided in the Supplemental Material (Table S1).

126 patients (54%) assigned to anterior–lateral electrode positioning and in 77 patients (33%) assigned to anterior–posterior electrode positioning. The risk difference was 22 percentage points (95% CI, 13–30; $P<0.001$), corresponding to a number needed to treat of 5 (95% CI, 3–8); the risk ratio was 1.69 ([95% CI, 1.35–2.11] Figure 3). The number of patients in sinus rhythm after the final shock was 216 patients (93%) assigned to anterior–lateral electrode positioning and 200 patients (85%) assigned to anterior–posterior electrode positioning. The risk difference was 7 percentage points (95% CI, 2–12), corresponding to a number needed to treat of 14 (95% CI, 8–50); the risk ratio was 1.10 (95% CI, 1.02–1.15). This difference persisted until discharge 2 hours after cardioversion (Table S3). Summarized characteristics related to the cardioversion procedure are provided in Table S4. Anterior–lateral electrode positioning resulted in a significantly reduced number of shocks applied when compared with anterior–posterior electrode positioning (Table S4). The benefit seen with anterior–lateral electrode positioning was consistent across the prespecified subgroups (Figure 4) and recruiting sites (Figure S1). There was significant interaction on the effect of electrode position on the outcome after the final shock when cardioverting obese patients (body mass index ≥30) versus nonobese patients (body mass index <30), and patients with their first AF episode versus patients with >1 AF episode. The risk difference after final shock for obese patients was 15 percentage points (95% CI, 5–25), with a risk ratio of 1.2 (95% CI, 1.05–1.36); for nonobese patients, the risk difference after final shock was 3 percentage points (95% CI, −3 to 9), with a risk ratio of 1.03 (95% CI, 0.96–1.10). The risk difference after final shock for patients with their first AF episode was 15 percentage points (95% CI, 8–23), with a risk ratio of 1.2 (95% CI, 1.08–1.30); the risk difference after final shock for patients with >1 AF episode was 1 percentage point (95% CI, −6 to 8), with a risk ratio of 1.01 (95% CI, 0.93–1.09).

Safety Outcomes

Cases of arrhythmia after cardioversion were rare. One patient assigned to anterior–posterior electrode positioning developed an advanced 2:1 atrioventricular block and was treated with pacemaker implantation. Two patients, 1 in each group, developed transient bradycardia (ie, heart rate <40 beats/min for ≥30 minutes), which resolved before discharge without requiring intervention. Early recurrence of AF (ie, within 1 minute after cardioversion) occurred in 10 patients (4.2%) assigned to anterior–lateral shocks and in 11 patients (4.7%) assigned to anterior–posterior shocks. Patient-reported periprocedural pain and skin redness were comparable between groups (Table S5).

DISCUSSION

In this large, multicenter, randomized trial, we found anterior–lateral electrode positioning resulted in significantly more patients obtaining sinus rhythm when compared with anterior–posterior electrode position for cardioverting AF. When using an anterior–lateral electrode position, the number of shocks needed to restore sinus rhythm was significantly reduced compared with an anterior–

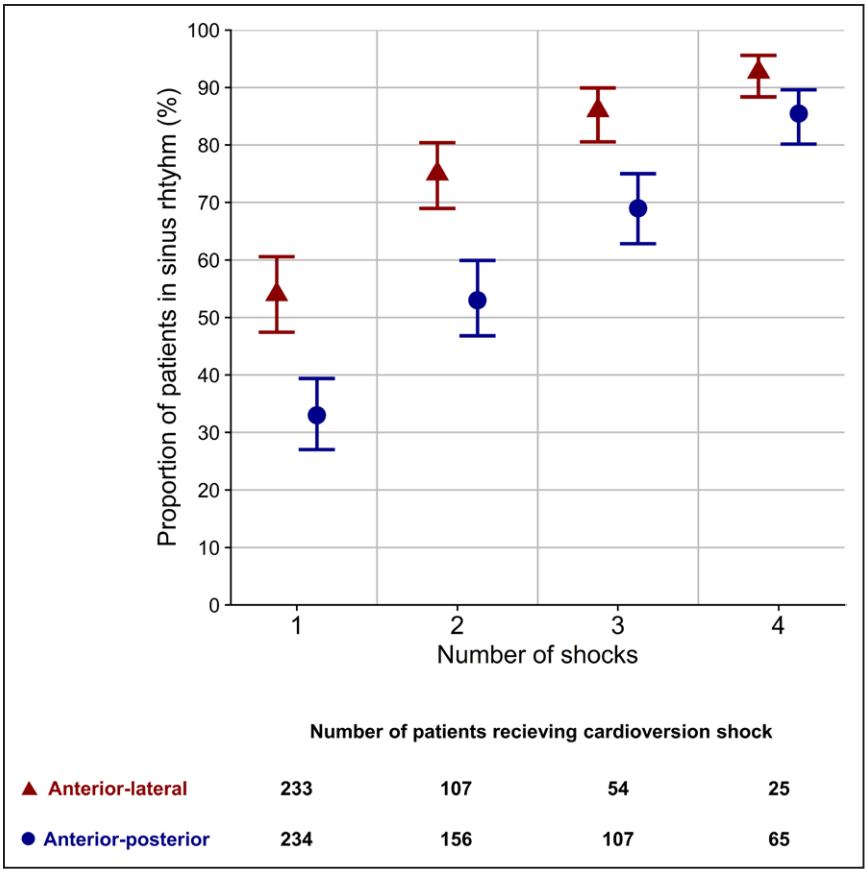

Figure 3. Main outcome figure illustrating the cardioversion success for anterior–lateral and anterior–posterior electrode position against the number of shocks applied. The summative outcomes after each cardioversion attempt are presented in Table S4.

posterior electrode position. There was no difference between groups in any safety outcome.

The benefit of the anterior–lateral electrode position when compared with the anterior–posterior electrode position has been uncertain as previous trials were generally too small and underpowered to detect a possible benefit of either electrode position.[22,23] Furthermore, the risk of bias was rated as high or unclear in 2 meta-analyses from 2014.[22,23] Thus, data from this definitive trial are warranted. Anterior–posterior electrode positioning is widely used in clinical practice and is often suggested as being superior to anterior–lateral electrode positioning.[16,17] This belief is largely based on 2 randomized studies that used monophasic shocks and showed anterior–posterior electrode positioning to be more effective than anterior–lateral electrode positioning.[5,8] However, other randomized studies using monophasic shocks have found no difference between electrode positions,[6,9,14] and 1 study found anterior–lateral superior to anterior–posterior electrode positioning.[7] These monophasic studies are not in line with contemporary clinical practice. As biphasic shocks are more effective and safer than monophasic shocks,[18–21] findings from studies using monophasic shocks may not translate to the contemporary use of biphasic shocks. Furthermore, the 2 studies favoring anterior–posterior electrode positioning used either hand-held paddles[8] or foil electrodes,[5] which is in contrast to the self-adhesive electrodes that are recommended today. The study from Kirchhof et al was of limited sample size (n=108) and terminated early because of an interim analysis suggesting superiority; therefore, the number of patients actually enrolled was reduced.[8]

In addition, anterior–lateral and anterior–posterior electrode positions have been compared in 6 randomized studies using biphasic shocks.[4,10–13,15] As for the studies on monophasic cardioversion, these studies showed varying results, likely reflecting risk of bias or inadequate sample sizes. Two small studies found anterior–lateral electrode positioning more effective than anterior–posterior electrode positioning,[13,15] whereas other studies found no difference between electrode positions.[4,10–12] Overall, these findings for biphasic cardioversion tended toward anterior–lateral position being superior to anterior–posterior electrode position, thus challenging the previous believe of anterior–posterior electrode position being superior.[22,23]

It is notable that the recent RAFF2 (Electrical Versus Pharmacological Cardioversion for Emergency Department Patients With Acute Atrial Fibrillation) trial showed no significant difference between the 2 electrode positions but did find a trend in favor of an anterior–lateral (88%) compared with an anterior–posterior (81%) electrode position for the first shock success. The study was designed to investigate (1) pharmacological cardioversion followed by electric cardioversion versus placebo followed by electric cardioversion; and

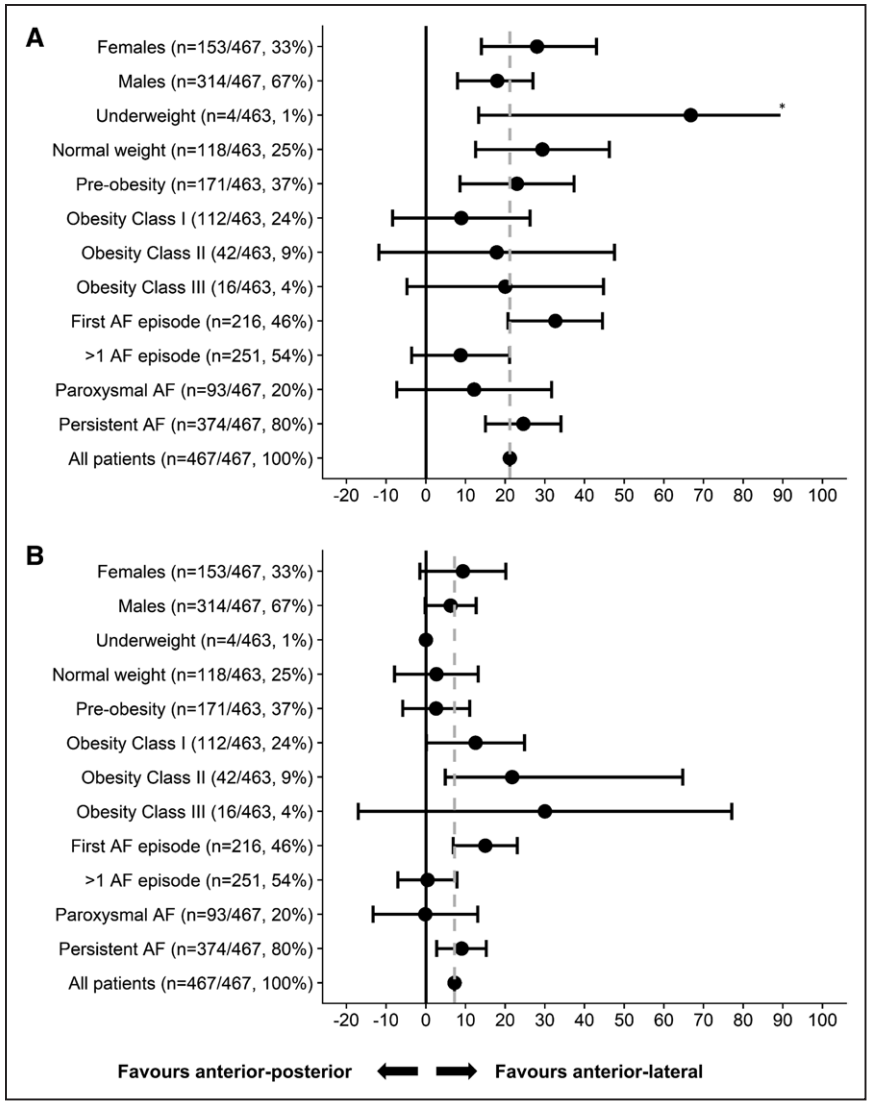

Figure 4. Forest plot of outcomes after cardioversion, by subgroups. **A**, Outcome after the first shock. *95% CI upper limit = 120. **B**, Outcome after the final shock, up to a maximum of 4 shocks. The World Health Organization classification of BMIs was used for subgroups (underweight, BMI<18.15; normal weight, BMI≥18.5 and BMI<25; preobesity, BMI≥25 and BMI<29; obesity class I, BMI≥30 and BMI<35; obesity class II, BMI≥35 and BMI<39; obesity class III, BMI≥39). Testing for interaction was statistically significant for first AF episode versus >1 AF episode (*P*=0.007 [first shock]; *P*=0.01 [final shock]) and for obesity (*P*=0.03 [final shock]). Dots indicate risk differences. Error bars = 95% CI. Dotted lines indicates the outcome in the overall population; solid lines indicates zero (ie, no difference). AF indicates atrial fibrillation; and BMI, body mass index.

(2) anterior–lateral versus anterior–posterior electrode positioning for electric cardioversion in a partial factorial design.[4] Because of the study design, some patients were pharmacologically cardioverted, which resulted in only 244 patients available for comparison on electrode positioning; therefore, the study may have been underpowered to detect a difference in electrode positions. Moreover, the study found a trend toward the need for fewer shocks to achieve sinus rhythm when using an anterior–lateral compared with an anterior–posterior electrode position, which is in line with our findings.[4]

The overall success rate in our study is in accordance with other cardioversion studies.[4,8,18–22,29] Our study population resembles a typical AF patient population of predominantly male, obese patients.[2] Persistent AF was most common, and all cardioversion procedures were performed as elective procedures in the cardiology department or outpatient settings. In the absence of specific recommendations on energy levels in international guidelines, the energy protocol adhered to the 2018 National Danish Guidelines on Cardioversion.[26] However, we also included a fourth shock of 360 J if necessary, which is the maximum energy available. During the conduction of this study, maximum fixed-energy shocks were found to be more effective than escalating low-energy shocks; maximum energy levels are now suggested in European guidelines.[2] It is notable that we found that anterior–lateral electrode positioning was more effective than anterior–posterior electrode positioning even when escalating to maximum energy.

The underlying biological mechanism by which an anterior–lateral electrode position—as compared with an anterior–posterior electrode position—increases cardioversion efficacy requires further investigation. Anterior–posterior shocks have a shock vector that is directed to selectively target the left atrium. In contrast, the anterior–lateral shock vector may result in more myocardial cells being cardioverted overall. Myocardial cells are sensitive to the direction of the shock vector.[30] Anterior–lateral shocks may possibly provide a more favorable shock vector, and thereby increase efficacy.

In our study, complications after cardioversion were rare. We did not experience cases of skin burns, and patients rarely experienced skin discomfort after cardioversion. This is in accordance with other studies suggesting that cardioversion using biphasic shocks is a safe procedure.[21,29] The primary outcome was consistent across the predefined subgroups. The benefit of anterior–lateral electrode position on success at discharge appeared greater for persistent AF and obese patients.

Beyond the improved efficacy, the use of anterior–lateral electrode position may have some practical advantages. In some situations, anterior–posterior electrode positioning may not be possible or feasible because of practical reasons (eg, during pacemaker implantation or AF ablation). In cases where immediate cardioversion is mandated in a deteriorating patient, anterior–lateral electrode positioning may be more convenient and possibly faster to apply. Furthermore, in cases where transcutaneous pacing is needed, anterior–lateral electrode positioning is the common standard. In order to maximize cardioversion efficacy, manual pressure applied to electrodes in the anterior–lateral position may increase efficacy.[31,32] Our results support that anterior–lateral electrode positioning should be used as a standard for cardioverting AF.

Limitations

First, because of the nature of the study, the treating clinicians were not blinded to the electrode position used. We do not believe that the open-label study design affected the cardioversion success; also, we used a blinded, central outcome assessment for the primary outcomes. Second, we investigated the anterior–lateral and anterior–posterior electrode positions that are recommended in international guidelines and that are clinically used in our institutions most often.[25] However, we acknowledge that there may be other alternative electrode positions of interest (eg, right anterior–posterior or apex–anterior positions).[4] Even though we saw a significant difference when escalating to maximum energy, it is unknown whether initial maximum energy shocks would result in a different outcome. Last, include neither patients undergoing acute cardioversion nor patients with implanted devices.

Conclusions

This study found anterior–lateral electrode positioning to be more effective than anterior–posterior electrode positioning for AF cardioversion. There were no significant differences in any safety outcome.

ARTICLE INFORMATION

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Disclosures

Dr Schmidt received a consulting fee from Ooono A/S. Dr Møller has been an advisory board member for Bayer and has received speaker's honoraria from Bayer, Bristol Meyers Squibb, Boehringer Ingelheim, Merck Sharp and Dohme, and Pfizer. All other authors have nothing to disclose relevant to this study.

Supplemental Material

Investigators and Study Sites
Tables S1–S11
Figure S1

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