Anterior-posterior versus anterior-lateral electrode positions for external cardioversion of atrial fibrillation: a randomised trial


Summary

Background External cardioversion is a readily available treatment for persistent atrial fibrillation. Although anatomical and electrophysiological considerations suggest that an anterior-posterior electrode position should create a more homogeneous shock-field gradient throughout the atria than an anterior-lateral position, both electrode positions are equally recommended for external cardioversion in current guidelines. We undertook a randomised trial comparing the two positions with the endpoint of successful cardioversion.

Methods 108 consecutive patients (mean age 60 years [SD 16]) with persistent atrial fibrillation (median duration 5 months, range 0.1–120) underwent elective external cardioversion by a standardised step-up protocol with increasing shock strengths (50–360 J). Electrode positions were randomly assigned as anterior-lateral or anterior-posterior. If sinus rhythm was not achieved with 360 J energy, a single cross-over shock (360 J) was applied with the other electrode configuration. A planned interim analysis was done after these patients had been recruited; it was by intention to treat.

Findings Cardioversion was successful in a higher proportion of the anterior-posterior than the anterior-lateral group (50 of 52 [96%] vs 44 of 56 [78%], difference 23.7% [95% CI 9.1–37.8, p=0.009). Cross-over from the anterior-lateral to the anterior-posterior electrode position was successful in eight of 12 patients, whereas cross-over in the other direction was not successful (two patients). After cross-over, cardioversion was successful in 102 of 108 randomised patients (94%).

Interpretation An anterior-posterior electrode position is more effective than the anterior-lateral position for external cardioversion of persistent atrial fibrillation. These results should be considered in clinical practice, for the design of defibrillation electrode pads, and when guidelines for cardioversion of atrial fibrillation are updated.

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Introduction

Atrial fibrillation is the most common sustained cardiac arrhythmia, and incidence is increasing in an ageing population.4 Atrial fibrillation causes important morbidity and mortality through loss of haemodynamic function of the atria, uncontrolled ventricular rate, and risk of stroke.1,3 Restoration of sinus rhythm is therefore a main treatment goal in patients with persistent atrial fibrillation.4 Transcutaneous external electrical cardioversion is the standard method to restore sinus rhythm in such patients,6 but it is not successful in every case.5,4 Means of improving the method of external cardioversion are therefore clinically and socioeconomically important.

Termination of fibrillatory activity can be achieved by creation of a shock-field gradient of at least 5 V/cm throughout the fibrillating myocardium for a few milliseconds.9,10 Since the right and left atria are positioned one behind the other, an electrical shock field between the anterior and posterior thorax may be more efficient at achieving such a shock-field gradient in the atria than that with electrodes positioned anteriorly and laterally on the anterior thorax. Furthermore, some evidence suggests that transthoracic impedance is lower anterior-posterior than anterior-lateral electrode positions may be better.11,12

Botto and colleagues13 suggested that anterior-posterior paddle positions may increase cardioversion success rates, but others have found no difference13,15 or have even suggested that anterior-lateral electrode positions may be better.14 Present guidelines therefore equally recommend either electrode position for external cardioversion.6,16

In a 1998 statement by a study group of the Working Group on Arrhythmias of the European Society of Cardiology,7 the need for better classification of atrial fibrillation was emphasised, as were the implications for studies that assess maintenance of sinus rhythm. These considerations were not taken into account fully by previous studies. We therefore designed a prospective randomised trial to test whether an anterior-posterior electrode position improves cardioversion success compared with an anterior-lateral position during external cardioversion of persistent atrial fibrillation.

Methods

Patients We screened all patients aged 18–80 years who were undergoing cardioversion at the Department of Cardiology of the University of Münster, Germany between May, 1999, and November, 2000. Patients with a pectorally implanted pacemaker or defibrillator were not included in this trial, but were cardioverted in the anterior-posterior position.7 Care was taken to exclude patients with atrial flutter or rapid atrial tachycardias; skilled cardiologists, including at least one electrophysiologically trained attending physician of our department analysed a 12-lead electrocardiogram (ECG) recorded on the day before cardioversion. Patients were...
excluded from the study when regular P waves (atrial cycle length >200 ms) were present in the limb leads throughout the surface ECG. Most of these patients underwent an invasive electrophysiological study to confirm the presence of atrial flutter or atrial tachycardia, and to attempt radio frequency catheter ablation. Duration of paroxysmal and persistent atrial fibrillation was assessed from ECG documentation of atrial fibrillation and the patient's history. All antiarrhythmic agents taken at the time of cardioversion were recorded, as were the patient's size and weight. Left and right atrial sizes were measured by biplane echocardiography.

**Design and procedures**

All study patients were randomly assigned to undergo cardioversion via anterior-laterally or anteriorly and posteriorly positioned hand-held cardioversion electrodes. Patients were assigned the randomised treatment directly before cardioversion from a computer-generated randomisation list. This list was concealed from the physicians and people scheduling and undertaking the cardioversion, and only the assignment for the present patient could be read by the nurse who held the list.

All cardioversions were done with an identical cardioversion shock. If atrial fibrillation persisted, we step-wise chose a predefined higher energy (100 J, 200 J, 300 J, 360 J), and attempted cardioversion again with the same electrode position. If atrial fibrillation persisted after the 360 J shock, we repositioned the electrodes and attempted cardioversion at 360 J with the other electrode position (cross-over).

The study complied with all applicable regulations for the conduct of research in patients, including the Declaration of Helsinki, and was approved by the local ethics committee. All patients gave written informed consent before inclusion. Patients were followed up for procedure-related adverse events in hospital for 24 h.

The primary endpoint was cardioversion success rate. Secondary endpoints included cardioversion success rate for each of the predefined shock energies and success rates after cross-over.

**Statistics**

The sample size was calculated as 100 patients per group, designed to detect a difference in cardioversion success rate of 15% based on an assumed success rate of 75% in the anterior-posterior electrode position (α=0·05, β=0·8). An interim analysis was planned after inclusion of 50 patients in each group. Randomisation was done with a block size of 50 patients per group to ensure equal group sizes at the interim analysis. To terminate the study after that interim analysis, an α error of less than 0·005 was specified. Analyses were by intention to treat. We compared success rates with the χ2 test. All calculations were made by an SPSS software package (version 8.0).

**Results**

We terminated the study after the interim analysis. At that time, 167 patients had been screened, and 100 were eligible and gave consent. At the termination point, cardioversion had been successful in a significantly higher proportion of patients treated in the anterior-posterior electrode position than in the anterior-lateral position (49 [98%] of 50 vs 39 [78%] of 50, difference 0·22 [95% CI 0·089–0·352]; p=0·004). During the time needed for the interim analysis, eight further patients were randomised. All subsequent analyses were based on the 108 patients randomised (52 anterior-posterior, 56 anterior-lateral; figure 1).

Table 1 shows the clinical characteristics of the 108 patients. 79 (73%) patients had accompanying cardiac disease. Atrial fibrillation had persisted for a median duration of 5 months (range 3 days to 120 months). At the time of cardioversion, 80 (74%) patients were taking antiarrhythmic drugs for prevention of recurrent atrial fibrillation and 20 were taking amiodarone (table 2). The mean number of antiarrhythmic agents being taken at the time of cardioversion was 1·8 (SE 0·1) overall, 1·6 (0·1) in the anterior-posterior group, and 2·0 (0·1) in the anterior-lateral group. Before taking part in the study, 52 (48%) patients had undergone external cardioversion at least once (range one to six times; table 1). The clinical characteristics and the distribution of antiarrhythmic agents taken did not differ significantly between the study groups, except for duration of persistent atrial fibrillation, which was slightly longer in

![Trial profile](image-url)
patients assigned the anterior-posterior electrode position (22·8, SD 18·3) than in those assigned to anterior-lateral electrode position (22·8, SD 37·1).

Cardioversion success rates were higher in the anterior-posterior position (9·4, SD 18·3) than in those assigned to anterior-lateral electrode position for all tested shock strengths (figure 2). Overall, cardioversion was successful in 8% of patients at 50 J and 4·5 J in those who were not.

Discussion
In this study, external cardioversion of persistent atrial fibrillation was more likely to be successful when an anterior-posterior electrode position was used. Furthermore, a change from the anterior-lateral to the anterior-posterior electrode position resulted in sinus rhythm in eight of 12 patients for whom cardioversion attempts had failed with the anterior-lateral electrode position. These findings suggest that an anterior-posterior electrode position is more effective for external cardioversion of atrial fibrillation than an anterior-lateral electrode position.

The difference in effectiveness of anterior-posterior electrodes can be explained by electroanatomical features. An anterior-posterior electrode position will include both atria directly within its shock field and thereby result in a more homogeneous shock field, especially within the posteriorly positioned left atrium. Therefore, positioning of electrodes in this way could be a more efficient way to create a shock-field gradient sufficient to terminate fibrillatory activity. Furthermore, the ostia of the pulmonary veins provide left-atrial anchors for the scroll waves maintaining atrial fibrillation, providing a stable substrate for successful cardioversion.

Table 2: Type and number of antiarrhythmic drugs being taken at cardioversion

<table>
<thead>
<tr>
<th>Drug</th>
<th>All patients (n=108)</th>
<th>Anterior-posterior group (n=52)</th>
<th>Anterior-lateral group (n=56)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium-channel blocker</td>
<td>16 (15%)</td>
<td>7 (13%)</td>
<td>9 (16%)</td>
</tr>
<tr>
<td>β-blocker</td>
<td>58 (54%)</td>
<td>26 (50%)</td>
<td>32 (57%)</td>
</tr>
<tr>
<td>Sotalol</td>
<td>24 (22%)</td>
<td>10 (19%)</td>
<td>14 (25%)</td>
</tr>
<tr>
<td>Calcium antagonist</td>
<td>8 (7%)</td>
<td>4 (8%)</td>
<td>4 (7%)</td>
</tr>
<tr>
<td>Digoxin</td>
<td>71 (66%)</td>
<td>36 (69%)</td>
<td>35 (63%)</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>20 (19%)</td>
<td>8 (15%)</td>
<td>12 (21%)</td>
</tr>
</tbody>
</table>

Numbers indicate the number of patients taking a specific class of drug.
shock-field gradients could therefore be crucial for cardioversion of atrial fibrillation. High left-atrial shock-field gradients are more likely to be achieved by anterior-posterior than by anterior-lateral shock fields owing to the posterior position of the left atrium in the thorax. In another similar study, anterior-posterior electrodes were no better than anterior-lateral electrodes. About 30% of the patients in that study presented with atrial flutter. Since its re-entrant circuit is confined to the right atrium, common and reverse-type common atrial flutter will be terminated by right-atrial cardioversion and therefore also when shock-field gradients are only sufficiently high in the anterior portion of the thorax. Furthermore, use of antiarrhythmic drugs in patients with atrial fibrillation has changed since that study was reported in 1981. These factors might have obscured a positive effect of anterior-posterior electrodes in that study. Although the clinical characteristics in our patients did not favour cardioversion success (long duration of atrial fibrillation, enlarged atria), cardioversion was achieved in almost all patients (94%) when an anterior-posterior electrode position was used. Higher overall failure rates in other studies, possibly caused by inclusion of a higher proportion of patients with permanent atrial fibrillation, might have obscured the positive effect of the anterior-posterior electrode position in other recent studies. Only one previous study, in which investigators recorded a high success rate, found that anterior-posterior electrodes were better for cardioversion than anterior-lateral electrodes. In that study, the clinical characteristics of the patients favoured successful cardioversion (short duration of atrial fibrillation, small left atria, and lower weight and body-mass index than in our study), yet the cardioversion rate was lower than in our study. In most of the previous studies the sample was too small for a negative result to be detected with sufficient statistical accuracy. The only study by Kerber and colleagues was sufficiently powered to detect a negative result. They, however, included a high proportion of patients with atrial flutter, possibly because the arrhythmia mechanisms of atrial flutter were incompletely understood at that time. The study design shows important differences between the published studies—eg, inclusion of differing proportions of patients with permanent, non-cardiovertible atrial fibrillation, technique for cardioversion, and patients’ characteristics. Although such differences are an important limitation for a meta-analysis, we analysed the effect of electrode position on cardioversion success in a meta-analysis of all published randomised patients and our own study group. This analysis confirmed a higher cardioversion success rate for the anterior-posterior electrode position (226 of 276 patients [82%] anterior-posterior vs 214 of 282 patients [76%] anterior-lateral, p=0.082). The mean effective cardioversion energy in our study was high (>200 J for both electrode positions), which is in keeping with reports suggesting that an initial energy of at least 200 J may be needed for successful cardioversion of most patients. If our protocol had defined an initial energy of 200 J instead of 50 J, about 25% of the patients would have received a higher than necessary shock, but unsuccessful low-energy shocks would have been avoided in about 75% of patients. These considerations might lend support to the claim that a high initial energy (200 J or 360 J) is appropriate for external cardioversion of persistent atrial fibrillation. However, neither use of multiple shocks nor repeated use of high-energy shocks (six shocks with two bursts of 360 J in 14 patients) resulted in major complications; thus, both a low initial shock energy and repeated high-energy shocks seemed to be safe. We used gel-covered hand-held electrodes, including a specially designed sintered-steel back pad. Some investigators have suggested that hand-held electrodes decrease transthoracic impedance, similarly to anterior-posterior electrodes. Some thereby resulted in higher intrathoracic shock-field gradients for a given shock energy. Use of hand-held steel electrodes for cardioversion might have contributed to the success rate of cardioversion in our study. The high success rate could also have been caused by some unidentified selection factors of patients undergoing cardioversion in our institution compared with other study populations. Long-term maintenance of sinus rhythm was not monitored in this study.

References