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

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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.[1] Atrial fibrillation causes important morbidity and mortality through loss of haemodynamic function of the atria, uncontrolled ventricular rate, and risk of stroke.[2,3] Restoration of sinus rhythm is therefore a main treatment goal in patients with persistent atrial fibrillation.[4] Transthoracic external electrical cardioversion is the standard method to restore sinus rhythm in such patients,[5,6] but it is not successful in every case.[4,7,8] 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.[9–11] 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 for anterior-posterior electrodes.[12,13]

Botto and colleagues[14] suggested that anterior-posterior paddle positions may increase cardioversion success rates, but others have found no difference[7,15] or have even suggested that anterior-lateral electrode positions may be better.[16] Present guidelines therefore equally recommend either electrode position for external cardioversion.[8,17]

In a 1998 statement by a study group of the Working Group on Arrhythmias of the European Society of Cardiology,[4] 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.[8] 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

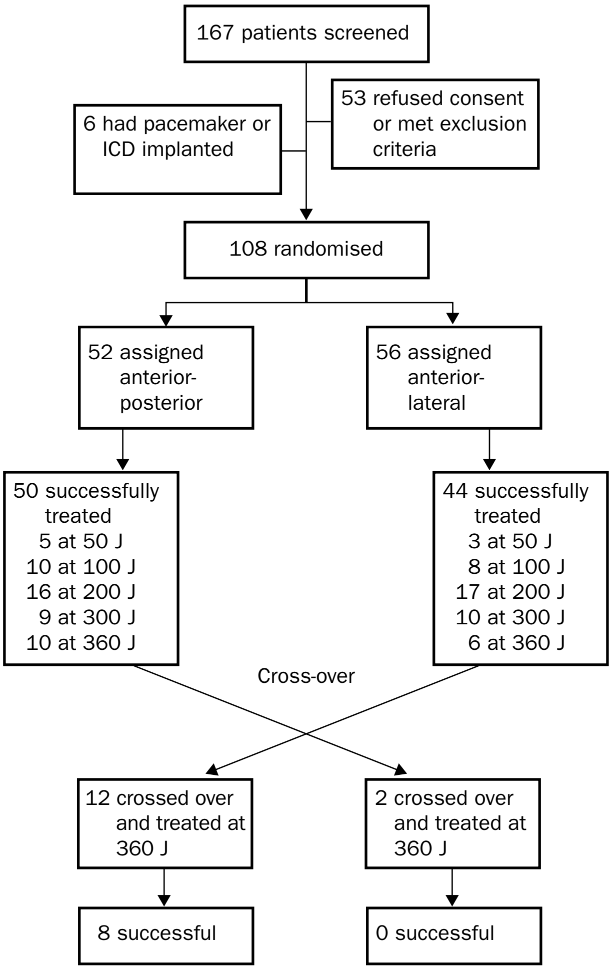

Figure 1: **Trial profile**
ICD=implantable cardioverter-defibrillator; AP=anterior-posterior, AL=anterior-lateral.

excluded from the study when regular P waves (atrial cycle length >200 ms) were present in the limb leads throughout the surface ECG.[4,18] 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 defibrillator (Physiocontrol Hellige Marquette LifePak 9, Düsseldorf), which applied monophasic shock waveforms through hand-held sintered steel electrodes covered by conducting gel. For the posterior electrode, a specifically designed back electrode was used (12 cm electrode diameter, Physiocontrol Hellige Marquette). We took care to position the cardioversion electrodes reproducibly.[8] Cardioversion was attempted with different preselected shock energies, starting at 50 J. Successful cardioversion was defined as termination of fibrillatory activity and presence of sinus rhythm or another organised atrial rhythm as shown by a six-lead ECG recorded after the 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,[19] 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-lateral 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 χ^2 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 (0·10) 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 antiarrythmic agents taken did not differ significantly between the study groups, except for duration of persistent atrial fibrillation, which was slightly longer in

	Anterior-posterior (n=52)	Anterior-lateral (n=56)
Demographic		
Age (years)	62 (2)	58 (2)
Men/women	38/14	44/12
Anthropometric		
Weight (kg)	82 (15)	85 (15)
Body-mass index (kg/m^2)	27 (4)	27 (4)
Atrial		
Left atrial diameter (mm)	51 (7)	49 (6)
Number of previous cardioversion attempts	1·0 (0·2; range 0–6)	0·6 (0·1; range 0–3)
Duration (median [range], months)	5 (0·1–120)	4 (0·1–120)
Cardiac disease		
Coronary-artery disease	13 (25%)	14 (25%)
Dilated cardiomyopathy	7 (13%)	13 (23%)
Hypertrophic cardiomyopathy	3 (6%)	3 (5%)
Conduction disturbance	6 (12%)	2 (4%)
Myocarditis	1 (2%)	0
Hypertension (blood pressure >140/90 mm Hg)	29 (56%)	22 (39%)
Previous stroke or transient neurological deficit	5 (10%)	2 (4%)
Atrial or ventricular septal defect	3 (6%)	2 (4%)
Lone atrial fibrillation	14 (23%)(27%)	15 (27%)

Values are number (%) or mean (SD), unless otherwise stated.

Table 1: **Clinical characteristics of the randomised patients**

patients assigned the anterior-posterior electrode position (22·8, SD 37·1) than in those assigned to anterior-lateral position (9·4, SD 18·3).

In the 108 randomised patients, cardioversion was successful in a larger proportion of the anterior-posterior than the anterior-lateral group (50 of 52 patients [96%; 95% CI 86·7–99·5] *vs* 44 of 56 [78%; 57·2–85·0], p=0·009). The difference in success rate was 23·7% (95% CI 9·1–37·8). When cardioversion failed in the randomly assigned electrode position, a single 360 J shock in the other electrode position (crossover) restored sinus rhythm in eight of 12 patients who crossed from anterior-lateral to anterior-posterior electrode position. Cardioversion was not successful in either of two patients who crossed from anterior-posterior to anterior-lateral electrode position.

Cardioversion success rates were higher in the anterior-posterior than the anterior-lateral electrode position for all of the tested shock strengths (figure 2). Overall, cardioversion was successful in 8% of patients at 50 J and in 25% at 100 J shock energy. When cardioversion was successful, the mean energy for cardioversion did not differ between the two electrode positions (mean energy for successful cardioversion anterior-posterior 212 J [SD 105] *vs* anterior-lateral 211 J [94]). Of the 60 patients taking drugs that block sodium or potassium channels (including amiodarone) at the time of cardioversion, the procedure was successful in all of 25 treated in the anterior-posterior electrode position and in 28 of 35

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

Numbers indicate the number of patients taking a specific class of drug.

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

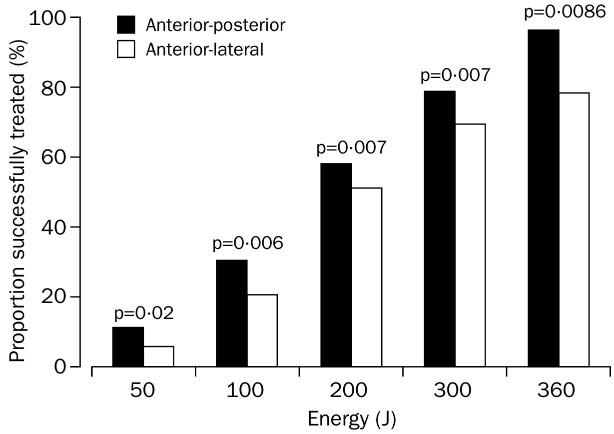

Figure 2: **Cumulative proportion of patients with successful cardioversion according to shock strength and electrode position**

Patients with successful cardioversion at one strength of shock were assumed to have been successfully treated at all higher strengths. p values are for difference between groups after exclusion of patients with successful cardioversion at lower shock strengths.

(80%) treated in the anterior-lateral position (p=0·02). Of the 49 patients not taking such antiarrhythmic drugs, the difference in success rate was not significant (25 of 27 [93%] *vs* 16 of 21 [76%], p=0·11).

The six patients who were not successfully cardioverted even after crossover had some distinct clinical characteristics. Their body-mass index was higher than that of patients successfully cardioverted (29·8 [SD 2·8] *vs* 26·8 [4·2] kg/m^2; p=0·02), all had left-atrial enlargement, and the duration of atrial fibrillation was longer (median 15 [range 7–24] months in those cardioverted and 4·5 [0·1–120] in those who were not).

We undertook a logistic regression analysis of potential factors affecting cardioversion success in our study: atrial size, duration of atrial fibrillation before cardioversion, antiarrhythmic drugs taken at the time of cardioversion, body-mass index, and electrode position. Two factors were identified as independent predictors of cardioversion success by this analysis: an anterior-posterior electrode position (odds ratio 11·8 [95% CI 1·8–78·1], p=0·01) and a low body-mass index (0·80 [0·66–0·96], p=0·2).

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.[11,20] Furthermore, the ostia of the pulmonary veins provide left-atrial anchors for the scroll waves maintaining atrial fibrillation,[21] and left-atrial shock-field gradients could therefore be crucial for cardioversion of atrial fibrillation.[22] 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,[7] anterior-posterior electrodes were no better than anterior-lateral electrodes. About 30% of the patients in that study presented with atrial flutter.[7] Since its re-entrant circuit is confined to the right atrium,[23,24] 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.[7]

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,[4] might have obscured the positive effect of the anterior-posterior electrode position in other recent studies.[15,16] Only one previous study,[14] 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.[14–16] Only the study by Kerber and colleagues[7] 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[14–16] 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.[25] 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.[25,26] 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,[12] similarly to anterior-posterior electrodes,[27,28] thereby resulting 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 after successful cardioversion depends on factors other than acute cardioversion success, such as the extent of atrial remodelling and of structural alterations in the atria, or the presence of focal triggers of atrial fibrillation.[29–31] Maintenance of sinus rhythm was not monitored in this study.

Contributors

P Kirchhof, L Eckardt, P Loh, K Weber, D Böcker, and M Borggrefe gathered the data. P Kirchhof, M Borggrefe, G Breithardt, W Haverkamp, and D Böcker designed and initiated the study and contributed to interpretation and discussion of the data. R-J Fischer was the statistical adviser and contributed to study design and data analysis. K-H Seidl contributed to interpretation and discussion of the data and writing of the report. P Kirchhof, M Borggrefe, R-J Fischer, L Eckardt, P Loh, W Haverkamp, and G Breithardt contributed to the review process.

Conflict of interest statement

None declared.

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References

1 Benjamin EJ, Wolf PA, D'Agostino RB, Silbershatz H, Kannel WB, Levy D. Impact of atrial fibrillation on the risk of death: the Framingham Heart Study. *Circulation* 1998; **98:** 946–52.
2 Wolf PA, Benjamin EJ, Belanger AJ, Kannel WB, Levy D, D'Agostino RB. Secular trends in the prevalence of atrial fibrillation: the Framingham Study. *Am Heart J* 1996; **131:** 790–95.
3 Kannel WB, Wolf PA, Benjamin EJ, Levy D. Prevalence, incidence, prognosis, and predisposing conditions for atrial fibrillation: population-based estimates. *Am J Cardiol* 1998; **82:** 2N–9N.
4 Levy S, Breithardt G, Campbell RW, et al. Atrial fibrillation: current knowledge and recommendations for management. *Eur Heart J* 1998; **19:** 1294–320.
5 Lown B, Amarasinghem R, Neumann J. New method for termination of cardiac arrhythmias: use of synchronized capacitor discharge. *JAMA* 1962; **182:** 548–55.
6 Pantridge J, Halmos P. Conversion of atrial fibrillation by direct current counter shock. *Br Heart J* 1965; **27:** 128–30.
7 Kerber RE, Jensen SR, Grayzel J, Kennedy J, Hoyt R. Elective cardioversion: influence of paddle-electrode location and size on success rates and energy requirements. *N Engl J Med* 1981; **305:** 658–62.
8 Kerber RE. Transthoracic cardioversion of atrial fibrillation and flutter: standard techniques and new advances. *Am J Cardiol* 1996; **78:** 22–26.
9 Chen PS, Swerdlow CD, Hwang C, Karagueuzian HS. Current concepts of ventricular defibrillation. *J Cardiovasc Electrophysiol* 1998; **9:** 553–62.
10 Dillon SM, Kwaku KF. Dynamics of postshock activation during defibrillation. In: Zipes DP, Jalife J, eds. Cardiac electrophysiology: from cell to bedside. Philadelphia: WB Saunders, 1999: 423–31.
11 Walcott GP, Knisley SB, Zhou X, Newton JC, Ideker RE. On the mechanism of ventricular defibrillation. *PACE* 1997; **20:** 422–31.
12 Ewy GA. Optimal technique for electrical cardioversion of atrial fibrillation. *Circulation* 1992; **76:** 1645–47.
13 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:** 676–82.

14 Botto GL, Politi A, Bonini W, Broffoni T, Bonatti R. External cardioversion of atrial fibrillation: role of paddle position on technical efficacy and energy requirements. *Heart* 1999; **82:** 726–30.

15 Mathew TP, Moore A, McIntyre M, et al. Randomised comparison of electrode positions for cardioversion of atrial fibrillation. *Heart* 1999; **81:** 576–79.

16 Alp N, Rahman S, Bell J, Shahi M. Randomised comparison of antero-lateral versus antero-posterior paddle positions for DC cardioversion of persistent atrial fibrillation. *Int J Cardiol* 2000; **75:** 211–16.

17 Yurchak PM, Williams SV, Achord JL, et al. Clinical competence in elective direct current (DC) cardioversion: a statement for physicians from the AHA/ACC/ACP Task Force on Clinical Privileges in Cardiology. *Circulation* 1993; **88:** 342–45.

18 Saoudi N, Cosio F, Waldo A, et al. Classification of atrial flutter and regular atrial tachycardia according to electrophysiologic mechanism and anatomic bases: a statement from a joint expert group from the Working Group of Arrhythmias of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *J Cardiovasc Electrophysiol* 2001; **12:** 852–66.

19 World Medical Association Declaration of Helsinki. Recommendations guiding physicians in biomedical research involving human subjects. *Cardiovasc Res* 1997; **35:** 2–3.

20 Newton JC, Knisley SB, Zhou X, Pollard AE, Ideker RE. Review of mechanisms by which electrical stimulation alters the transmembrane potential. *J Cardiovasc Electrophysiol* 1999; **10:** 234–43.

21 Cox JL, Schuessler RB, Lappas DG, Boineau JP. An 8 1/2-year clinical experience with surgery for atrial fibrillation. *Ann Surg* 1996; **224:** 267–73.

22 Gray RA, Ayers G, Jalife J. Video imaging of atrial defibrillation in the sheep heart. *Circulation* 1997; **95:** 1038–47.

23 Feld GK, Fleck RP, Chen PS, et al. Radiofrequency catheter ablation for the treatment of human type 1 atrial flutter. Identification of a critical zone in the reentrant circuit by endocardial mapping techniques. *Circulation* 1992; **86:** 1233–40.

24 Shah DC, Jais P, Haissaguerre M, et al. Three-dimensional mapping of the common atrial flutter circuit in the right atrium. *Circulation* 1997; **96:** 3904–12.

25 Joglar JA, Hamdan MH, Ramaswamy K, et al. Initial energy for elective external cardioversion of persistent atrial fibrillation. *Am J Cardiol* 2000; **86:** 348–50.

26 Ricard P, Levy S, Trigano J, et al. Prospective assessment of the minimum energy needed for external electrical cardioversion of atrial fibrillation. *Am J Cardiol* 1997; **79:** 815–16.

27 Kerber RE, Kouba C, Martins J, et al. Advance prediction of transthoracic impedance in human defibrillation and cardioversion: importance of impedance in determining the success of low-energy shocks. *Circulation* 1984; **70:** 303–08.

28 Aylward PE, Kieso R, Hite P, Charbonnier F, Kerber RE. Defibrillator electrode-chest wall coupling agents: influence on transthoracic impedance and shock success. *J Am Coll Cardiol* 1985; **6:** 682–86.

29 Haissaguerre M, Jais P, Shah DC, et al. Spontaneous initiation of atrial fibrillation by ectopic beats originating in the pulmonary veins. *N Engl J Med* 1998; **339:** 659–66.

30 Franz MR, Karasik PL, Li C, Moubarak J, Chavez M. Electrical remodeling of the human atrium: similar effects in patients with chronic atrial fibrillation and atrial flutter. *J Am Coll Cardiol* 1997; **30:** 1785–92.

31 Hohnloser SH, Kuck KH, Lilienthal J. Rhythm or rate control in atrial fibrillation–Pharmacological Intervention in Atrial Fibrillation (PIAF): a randomised trial. *Lancet* 2000; **356:** 1789–94.