Atrial fibrillation 2: management

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Chemical or electrical cardioversion of atrial fibrillation is attempted when spontaneous conversion to sinus rhythm does not occur. Sinus rhythm following cardioversion should be maintained with antiarrhythmic drugs. Non-pharmacological methods are reserved for highly symptomatic patients not controlled by, or intolerant of, medications.

During the last decade the traditional management of atrial fibrillation (AF) has involved terminating the dysrhythmia by electrical or pharmacological cardioversion and maintaining the sinus rhythm in paroxysmal and persistent AF (rhythm control), controlling the ventricular rate during a paroxysm of AF or when rhythm control is unsuccessful in persistent and permanent AF (rate control), and preventing embolic events by anticoagulation. This review discusses the evidence for current management of rhythm disturbance in AF.

CARDIOVERSION

New-onset AF has a high rate of spontaneous conversion to sinus rhythm within 24–48 hours (Capucci et al, 1992). If the arrhythmia is not self-limiting, however, cardioversion is usually attempted to restore sinus rhythm. Urgent cardioversion may become necessary when the arrhythmia results in acute heart failure, hypotension or worsening angina. Cardioversion is also performed electively to restore sinus rhythm in patients with persistent AF. Anticoagulation should be started before the procedure as cardioversion carries a risk of thromboembolism, greatest when the arrhythmia has been present for more than 48 hours.

PHARMACOLOGICAL CARDIOVERSION

Pharmacological cardioversion is considered most effective if initiated within the first week of onset of the arrhythmia (Costeas et al, 1998). Within this period restoration of sinus rhythm can be achieved in nearly 70% of patients, but the success rate is lower in AF of longer duration.

Guidelines on the management of AF (Fuster et al, 2001) suggest that flecainide, propafenone or ibutilide should be the first-line choice if pharmacological cardioversion of the arrhythmia is considered (*Table 1*). These drugs are effective for pharmacological cardioversion of recent onset AF (Donovan et al, 1991; Botto et al, 1997). They have not been evaluated extensively in patients with persistent AF, but available information on flecainide and propafenone suggests lower efficacy in this setting, while ibutilide seems to be more effective than placebo for pharmacological cardioversion of AF that has persisted longer than 1 week.

Capucci et al (1999) reported conversion rates after the administration of a single dose of flecainide or propafenone of 59% and 51% respectively at 3 hours compared to 18% on the placebo arm, and 78% and 72% at 8 hours compared to 39% on placebo. Left ventricular dysfunction, coronary artery disease or hypertension associated with ventricular hypertrophy ≥14 mm should be ruled out before flecainide is administered. Amiodarone usually acts less rapidly and probably less effectively than other antiarrhythmic agents. It has been proven effective for conversion

TABLE 1.
Class I and III antiarrhythmic drugs

Class I	Class IA	Procainamide
		Disopyramide
		Quinidine
	Class IB	Lidocaine
		Mexiletine
		Tocainide
	Class IC	Flecainide
		Propafenone
		Moricizine
Class III		Amiodarone
		Sotalol
		Bretylium
		Ibutilide

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of persistent AF in placebo-controlled trials (Galve et al, 1996), but its effectiveness in cardioverting recent-onset AF is modest. As a result of its delayed onset of action, conversion may not occur for several days (Kochiadakis et al, 1999). Sotalol, on the other hand, has no proven efficacy for pharmacological cardioversion of recent-onset or persistent AF (*Figure 1*) (Vos et al, 1998).

Use of antiarrhythmic drugs is not free from potential disadvantages. These drugs are proarrhythmic and their use is often associated with drug-induced torsade de pointes ventricular tachycardia or other serious arrhythmias. Furthermore, the interactions of antiarrhythmic drugs with oral anticoagulants may affect the pharmacokinetics of the latter, leading to a significant change in the anticoagulant effect. Therefore, caution should be exercised when these drugs are added to or withdrawn from the treatment regimen.

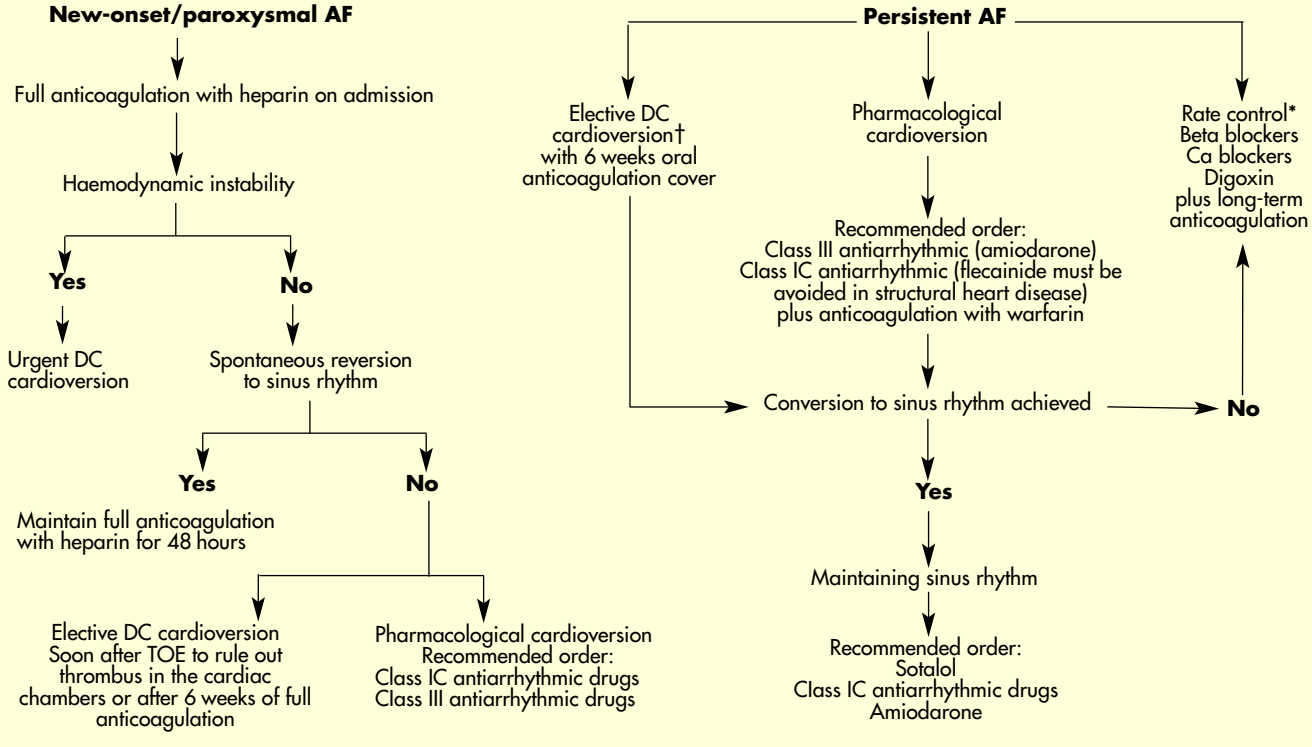
ELECTRICAL CARDIOVERSION

The success rates of electrical cardioversion of AF range from 70 to 90%. This variation is the result of the different definitions of success that ranged from immediate conversion after the electrical shock is applied to the presence of sinus rhythm several days afterward (Van Gelder et al, 1991). The likelihood of restoration and maintenance of sinus rhythm through cardioversion is low in AF that has been present for longer than 1 year. Successful cardioversion of AF depends also on the nature of the underlying heart disease and on structural abnormalities of the heart, e.g. left atrial enlargement and cardiomegaly.

The electrical shock should be properly synchronized with the QRS complex to sense the R wave on the electrocardiogram (ECG). This ensures that electrical stimulation does not occur during the vulnerable phase of the cardiac cycle, i.e. around the apex of the T wave. High energy is usually required for cardioversion of AF. In one study, 64 patients were randomly assigned to initial energy output of 100 J, 200 J or 360 J. Immediate success rates were 14% with 100 J, 39% with 200 J, and 95% with 360 J (Joglar et al, 2000). Higher levels of initial energy are significantly more effective than lower levels in achieving immediate cardioversion and fewer shocks and consequently less cumulative energy are required if 360 J is delivered initially.

Lundstrom and Ryden (1988) found that only 23% of patients with AF who had successful electrical cardioversion remained in sinus rhythm after 1 year and 16% after 2 years; in those who relapsed, repeated cardioversion with antiarrhythmic medication led to restoration and maintenance of sinus rhythm in 40% and 33% after 1 and 2 years respectively. Thus, unless

Figure 1. Initial management of atrial fibrillation (AF).



*Rate control is the initial step in the management of persistent or permanent AF in patients who have recurrent persistent AF with at least one previous electrical cardioversion, or those who have features indicate low likelihood of maintaining sinus rhythm such as large left atrium, significant left ventricular dysfunction, advanced age, history of heart failure, hypertension, and rheumatic heart disease. †If initial DC cardioversion fails to restore sinus rhythm, another attempt could be considered if the likelihood of success and/or maintaining sinus rhythm remains high. Concomitant antiarrhythmic drug therapy should preferably be given before the second attempt. Ca blockers = calcium-channel blockers; TOE = transoesophageal echocardiography

concomitant antiarrhythmic drug therapy is given, the rate of relapse following electrical cardioversion is high.

Practical considerations for electrical cardioversion

To increase the likelihood of successful cardioversion, it is important to deliver an appropriate current density to the atrial myocardium. Delivery is conversely related to transthoracic impedance, so the current density delivered decreases as the impedance increases for a given paddle surface area. Transthoracic impedance is affected by factors including the size and composition of the electrode paddles, the contact medium between the electrodes and the skin, the distance between the paddles, body size, phase of the respiratory cycle, number of shocks delivered, and interval between shocks. No definite information is yet available regarding the best paddle size that should be used for cardioversion of AF, but 8–12 cm diameter is generally recommended. Use of electrolyte-impregnated pads minimizes electrical resistance between the electrode pads and the skin and hence reduces the impedance.

Delivering the shocks during expiration reduces the amount of pulmonary tissue lying between the paddles and the heart, allowing higher levels of energy to reach the atrial myocardium. The same result could be achieved when using the anteroposterior paddle positioning (one paddle is placed on the sternum and the other on the left scapula) by placing the anterior electrode to the left of the sternum under the breast tissue so that the amount of interposed pulmonary tissue is reduced. Anteroposterior paddle positioning is probably better than the anterolateral position (ventricular apex and right infraclavicular area) (*Figure 2*). However, changing from one position to the other should be considered if the initial one proves unsuccessful.

The current density delivered to the atrial myocardium is also influenced by the output waveform. Cardiac defibrillators have traditionally used damped sine wave shocks (monophasic shocks). Biphasic waveform shocks have been found to be more effective at the same energy or as effective at less energy than monophasic shocks in restoring sinus rhythm. The lower current and energy generally required for successful defibrillation with biphasic waveforms presumably decrease the risk of tissue damage.

Transvenous electrical cardioversion is an alternative technique developed for patients who failed to respond to the conventional external technique. This type of cardioversion can be performed by delivering high-energy (200–300 J) direct current internally using a right atrium catheter and a backplate (Levy et al, 1988), or applying low-energy (less than 20 J) shocks via a large-surface cathodal electrode in the right atrium and an anode in the coronary sinus or left pulmonary artery (Levy et al, 1997) (*Figure 3*).

Electrical cardioversion carries some disadvantages. Embolic events and cardiac arrhythmias are the major complications, and the need for conscious sedation or anaesthesia might be problematic. Thromboembolic events occur in 1–7% of patients who do not receive prophylactic anticoagulation before cardioversion (Arnold et al, 1992). Different types of benign arrhythmias such as ventricular and supraventricular premature beats, bradycardia and short periods of sinus arrest may develop following electrical cardioversion, but they commonly subside spontaneously. More dangerous arrhythmias, e.g. ventricular tachycardia and fibrillation, may be precipitated in patients with hypokalaemia or digitalis intoxication. Transient ST segment elevation may develop after cardioversion and blood levels of creatine kinase may rise. However, troponin level does not significantly increase, suggesting that myocardial damage related to DC cardioversion does not occur (Lund et al, 2000).

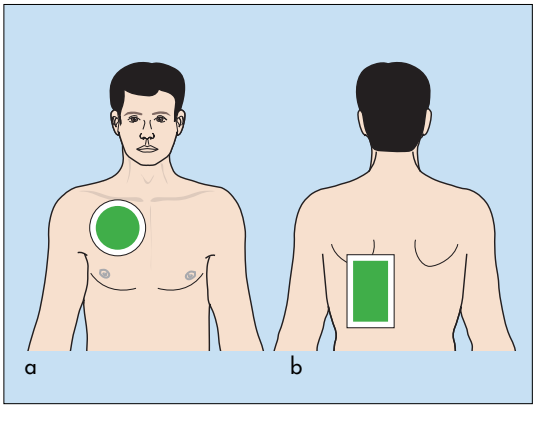
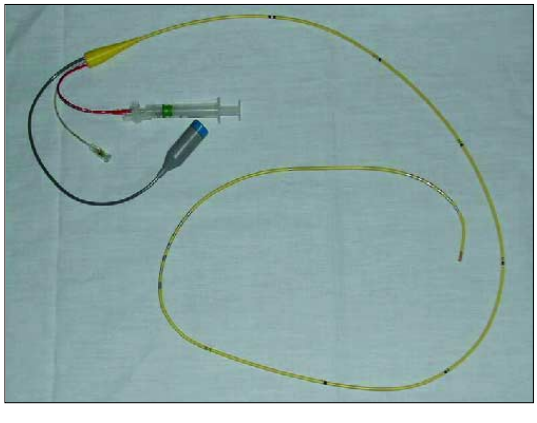


Figure 2. Different defibrillator paddle positions. a. Right infraclavicular paddle in anterolateral position (left). b. Left scapular paddle in anteroposterior position (right).

Figure 3. Right atrium catheter for transvenous electrical cardioversion.



MAINTENANCE OF SINUS RHYTHM

AF (whether paroxysmal or persistent) is a chronic disorder, and recurrence is likely in the majority of patients. These patients usually have significant symptoms related to paroxysmal AF or recurrence after cardioversion, and will require prophylactic treatment with antiarrhythmic drugs to maintain sinus rhythm. Clinical factors that increase the risk of recurrent AF include advanced age, history of heart failure, hypertension, rheumatic heart disease, left atrial enlargement and left ventricular dysfunction.

Van Gelder et al (1996) reported that, in patients with persistent AF, the 4-year arrhythmia-free survival rate was less than 10% after one electrical cardioversion without prophylactic drug therapy. This rose to approximately 30% following serial cardioversions and prophylactic drug therapy. Reversible cardiovascular and non-cardiovascular causes (e.g. thyrotoxicosis or high alcohol intake) that might precipitate AF should be treated or controlled to minimize the risk of recurrence. Prophylactic drug treatment is not usually indicated following the first episode of AF, and it could be avoided in patients with infrequent (less than one episode per 3 months) and well-tolerated paroxysmal AF.

Drug treatment

Various antiarrhythmic drugs have been investigated for maintenance of sinus rhythm in patients with AF. Class IC antiarrhythmic drugs such as propafenone and flecainide (*Table 1*) are better than placebo in maintaining sinus rhythm (Connoly and Hoffset, 1989; Pietersen and Hellemann, 1991). However, class I antiarrhythmic drugs have significantly increased the risk of all-cause and cardiac mortality, particularly in patients with structural heart disease. Hence, a shift was made towards more frequent use of class III antiarrhythmic drugs, e.g. amiodarone and sotalol. Data from randomized trials have demonstrated the efficacy and safety of amiodarone in such patients.

In the Canadian Trial of Atrial Fibrillation (CTAF), Roy et al (2000) found that amiodarone 200 mg per day resulted in a 57% reduction in risk of recurrence of AF compared with sotalol and propafenone. Similar results were found in the first antiarrhythmic drug substudy of the Atrial Fibrillation Follow-up Investigation of Rhythm Management (AFFIRM) trial where patients were randomized to amiodarone, sotalol or a class I antiarrhythmic drug as the first antiarrhythmic drug. The primary endpoint of the study was a composite endpoint of survival at 1 year in sinus rhythm with no cardioversion while still taking the assigned antiarrhythmic drug. The most successful drug for maintenance of sinus rhythm was amiodarone as 62% of patients treated with this drug met the primary endpoint. This endpoint was achieved in 39% and 23% of patients taking sotalol and class I agents respectively.

It is prudent to remember that, although amiodarone was shown to be the most effective drug for control of AF, it has the potential for serious systemic side effects in the long term. Therefore, it should be reserved for patients who have serious structural heart disease because it is less likely to further impair cardiac function.

When treatment with a single drug fails, combinations of antiarrhythmic drugs may be tried. Useful combinations include a beta-blocker, sotalol or amiodarone, plus a type IC agent. Sotalol has substantial beta-blocking activity and may therefore be chosen as the initial antiarrhythmic agent in patients with AF and underlying ischaemic heart disease.

CONTROLLING THE VENTRICULAR RATE DURING ATRIAL FIBRILLATION

It is essential to control the ventricular rate to alleviate symptoms of AF and prevent tachycardiomyopathy. This could be achieved by pharmacological intervention based mainly on blocking conduction across the atrioventricular (AV) node. Beta-blockers, calcium antagonists and digitalis glycosides are commonly used for this.

Clinical symptoms and ECG recordings are the main indicators of the adequacy of rate control during AF. The rate is generally considered controlled when the ventricular response ranges from 60 to 80 beats per minute at rest and 90 to 115 beats per minute during moderate exercise. Control of the heart rate at rest does not necessarily mean that the rate is well regulated during exercise. Excessive rate acceleration might occur during even mild exercise in patients with AF whose heart rates are well controlled at rest.

Digoxin is generally effective for rate control in persistent AF, particularly when congestive heart failure is present (Roberts et al, 1993). Digoxin was shown to be superior to placebo in controlling the resting heart rate (Segal et al, 2000). However, it does not slow the heart rate during exercise in patients with AF (Blumgart, 1924).

Beta-blockers are effective at controlling resting heart rate (Segal et al, 2000). Atenolol and nadolol are the most efficacious agents. Beta-blockers may also slow the heat rate during exercise, as atenolol provides better control of exercise-induced tachycardia than digoxin (Lewis et al, 1989). Long-term use of beta-blockers to control the heart rate in patients with

AF is generally safe. However, patients taking beta-blockers may experience excessively slow heart rates at rest and some deterioration of exercise tolerance (Segal et al, 2000).

Non-dihydropyridine calcium antagonists such as verapamil and diltiazem reduce both resting heart rate and exercise-induced tachycardia significantly better than placebo, and preserve or even improve exercise tolerance in most patients (Segal et al, 2000). They are preferred over beta-blockers for long-term use in patients with chronic obstructive pulmonary disease. They should be used with caution in patients with heart failure as they have a negative inotropic effect.

Combinations of these agents may often be required to achieve adequate rate control, but care should be taken to avoid excessive slowing of the heart rate. In general, the combination of digoxin and beta-blockers appears to be more effective than the combination of digoxin and diltiazem (Farshi et al, 1999).

RATE CONTROL OR RHYTHM CONTROL?

The decision to convert AF into sinus rhythm is generally taken to relieve symptoms, prevent systemic embolism and avoid long-term anticoagulation. For these reasons, cardioversion and rhythm control were thought to be better than rate control in recurrent AF. Pharmacological treatment of AF can convert a symptomatic arrhythmia to an entirely asymptomatic one. In a study of more than 1000 patients with AF by Fetsch et al (2004), antiarrhythmic drug therapy rendered 90% of arrhythmia recurrences completely asymptomatic. These observations challenged the validity of symptoms for reliable detection of recurrence of AF and for the assessment of the efficacy of antiarrhythmic drug therapy as well as the safety of discontinuation of anticoagulants.

Evidence from two large randomized trials showed that rhythm control provides no advantage over ventricular rate control with respect to survival (Van Gelder et al, 2002; Wyse et al, 2002). In fact the trend favoured rate control over rhythm control, even after adjustment for age, left ventricular ejection fraction, congestive heart failure, coronary artery disease and hypertension. This mainly relates to the fact that patients on rate control treatment continued to be anticoagulated with warfarin.

There was also no difference between the two strategies with regard to the secondary composite endpoint of total mortality, major bleeding, cardiac arrest, and disabling stroke or anoxic encephalopathy. The incidence of ischaemic stroke was 1% per year in both groups. However, patients in the rhythm control arm required hospitalization during the study period significantly more often than patients in the rate control arm (80.1% *vs* 73.0% respectively). Moreover, in the rhythm control group, women and hypertensive patients were especially susceptible to adverse outcomes (Van Gelder et al, 2002). The authors concluded that rate control should be considered a primary approach to therapy and that rhythm control, if used, may be abandoned early if it is not fully satisfactory.

AV NODAL ABLATION

AV nodal ablation that requires permanent pacemaker implantation provides a very effective means of controlling rapid ventricular rate in symptomatic patients with AF that cannot be adequately controlled with antiarrhythmic or negative chronotropic medications (Wood et al, 2000). AV nodal ablation is especially useful for patients with declined ventricular systolic function induced by tachycardia resistant to medical therapy. In a meta-analysis of 21 studies including 1181 patients, Wood et al (2000) concluded that AV nodal ablation and permanent pacemaker implantation significantly improved cardiac symptom scores, quality-of-life measures, and health-care utilization for patients with highly symptomatic AF that was refractory to medical treatment.

Despite the symptomatic benefits of this intervention, its use has been associated with recognized complications that include:

- A greater rate of progression from paroxysmal to persistent AF
- Ventricular arrhythmias including torsade de pointes ventricular tachycardia that carries real risk of sudden death (Evans et al, 1991)
- Thromboembolism associated with discontinuation of anticoagulation
- Complications of pacemaker implantation.

PULMONARY VEIN ABLATION AND ISOLATION

The recognition that AF could result from arrhythmogenic foci, which often originate within the pulmonary veins, has led to the evolution of catheter ablation techniques that include direct ablation of these foci in the pulmonary vein or electrical isolation of the pulmonary vein from the left atrium (*Figure 4*) (Haissaguerre et al, 2000a).

Pulmonary vein ablation is usually conducted by delivering radiofrequency energy to the identified foci in the vein (focal ablation), or to the extension of left atrial myocardium into the pulmonary vein at the venoatrial junction (segmental ablation). Segmental ablation has a better clinical success than focal ablation with a lower recurrence rate. This is possibly because the for-

mer is associated with isolation of almost all potential foci in the pulmonary vein trunk. The initial success rate of segmental ablation was reported to be more than 90%, but almost half of patients had early recurrence and required repeated ablation procedures (Haissaguerre et al, 2000a,b). Pulmonary vein ablation is associated with rare but recognized major complications including symptomatic pulmonary vein stenosis, embolic phenomena, pericardial effusion or tamponade, and phrenic nerve paralysis.

The aim of pulmonary vein isolation from the left atrium is to create a complete conduction barrier at the venoatrial junction. This is achieved by applying circumferential lesions at either this junction or at atrial tissue surrounding the pulmonary veins. Two different techniques have been used. One is to deliver contiguous, multiple spot lesions of radiofrequency energy in a circumferential fashion, facilitated and assessed by a three-dimensional electroanatomical mapping system (Pappone et al, 2000). The other is to use a balloon-based catheter with an ultrasound transducer mounted near the tip in a saline-filled balloon to create a circumferential lesion at the pulmonary vein ostia (Natale et al, 2000). Over 80% of patients were free of AF without antiarrhythmic drugs after application of circumferential lesions on atrial tissue around the four pulmonary veins (Pappone et al, 2001), while using the ultrasound balloon to isolate pulmonary veins from atria resulted in successful outcome in only 60% of patients who remained free of AF without drugs at 9 months follow-up (Natale et al, 2000).

SURGICAL TREATMENT OF ATRIAL FIBRILLATION

The corridor and maze operations are the two main surgical procedures for preventing AF and maintaining sinus rhythm. The techniques are based on the pathological mechanism of wavelet reentry and the requirement of a critical mass of contiguous atrial tissue for sustaining the wavelet circuits and maintaining the arrhythmia. Precisely placed incisions in the atrial tissue can produce linear barriers to electrical conduction, and prevent formation of the reentrant wavelets.

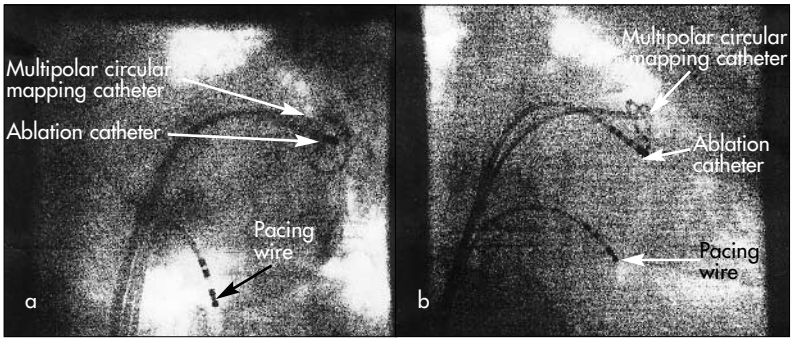
In the corridor operation, a strip of atrial septal muscle (including tissue from the sinus node area, the AV junction and the connecting right atrial mass) is isolated to prevent the wavelets from reaching the AV node while allowing the sinus impulse to conduct normally (Leitch et al, 1991). This operation, however, was associated with high rates of recurrence requiring re-operation or treatment with antiarrhythmic agents, and failed to improve the haemodynamic abnormalities associated with AF, and to abolish the need for anticoagulation, as most of the atrial tissue continued to fibrillate. The procedure was also complicated by postoperative sinus node dysfunction requiring permanent pacing in about a third of the patients (Van Hemel et al, 1994).

The maze procedure, introduced by Cox and colleagues in 1987, is highly successful in restoring sinus rhythm. It is designed to interrupt all potential reentrant circuits by making a series of incisions in the atria below these circuits, removing both atrial appendages, and isolating the pulmonary veins (Cox et al, 1991). AV synchrony is usually preserved and the risk of thromboembolism therefore eliminated (Cox, 1998). Initially, 40% of patients who had this procedure required postoperative permanent pacing for sinus node dysfunction, although most of these patients had preoperative evidence of this conduction abnormality. Better selection of patients and modifications of the original technique helped avoid excessive trauma in the area of the sinus node and significantly reduced this complication. Although the maze operation can cure AF in the majority of patients, it is an extensive and complicated procedure for a disorder with a relatively low mortality. Therefore, it is reserved for medically refractory patients with symptomatic recurrent arrhythmia or with chronic AF if there is evidence that restoration of sinus rhythm may result in significant haemodynamic benefit.

CONCLUSIONS

AF is the most common sustained rhythm disturbance. It is often associated with structural heart disease, and can cause haemodynamic impairment and thromboembolic events, which result in significant morbidity and mortality. The ideal treatment of this common arrhythmia is yet to be established. The current approach to the management of chronic AF is to accept the rhythm disturbance and to try to minimize its potential complications, i.e. tachycardiomyopathy and thromboembolism, although at least one attempt

Figure 4. Pulmonary vein ablation. (b) shows use of a lasso catheter.



at rhythm restoration, particularly in those with lone AF, should be undertaken. HM

Figure 2 *is reproduced from Shea and Maisel (2002) by kind permission. The author would like to thank Dr Howard Swanton who provided helpful criticism of the text, kind advice and support.*
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Arnold AZ, Mick MJ, Mazurek RP et al (1992) Role of prophylactic anticoagulation for direct current cardioversion in patients with atrial fibrillation or atrial flutter. *J Am Coll Cardiol* **19:** 851–5
Blumgart H (1924) The reaction to exercise of the heart affected by auricular fibrillation. *Heart* **11:** 4956
Botto GL, Capucci A, Bonini W et al (1997) Conversion of recent onset atrial fibrillation to sinus rhythm using a single oral loading dose of propafenone: comparison of two regimens. *Int J Cardiol* **58:** 55–61
Capucci A, Lenzi T, Boriani G et al (1992) Effectiveness of loading oral flecainide for converting recent onset atrial fibrillation to sinus rhythm in patients without organic heart disease or with only systemic hypertension. *Am J Cardiol* **70:** 69–72
Capucci A, Villani G, Piepoli M et al (1999) The role of oral IC antiarrhythmic drugs in terminating atrial fibrillation. *Curr Opin Cardiol* **14:** 4–8
Connoly SJ, Hoffset DL (1989) Usefulness of propafenon for recurrent paroxysmal atrial fibrillation. *Am J Cardiol* **63:** 817–19
Costeas C, Kassotis J, Blitzer M et al (1998) Rhythm management in atrial fibrillation- with a primary emphasis on pharmacological therapy: part 2. *PACE* **21:** 742–52
Cox JL, Schuessler RE, D'Agostino HJ Jr et al (1991) The surgical treatment of atrial fibrillation: lll. Development of a definitive surgical procedure. *J Thorac Cardiovasc Surg* **101:** 569–83
Cox JL (1998) Atrial transport function after the maze procedure for atrial fibrillation: a 10-year clinical experience. *Am Heart J* **136:** 934–6
Donovan KD, Dobb GJ, Coombs LJ et al (1991) Reversion of recent-onset atrial fibrillation to sinus rhythm by intravenous flecainide. *Am J Cardiol* **67:** 137–41
Evans GT Jr, Scheinman MM, Bardy G et al (1991) Predictors of in-hospital mortality after DC catheter ablation of atrioventricular junction: results of a prospective, international, multicenter study. *Circulation* **84:** 1924–37
Farshi R, Kistner D, Sarma JS et al (1999) Ventricular rate control in chronic atrial fibrillation during daily activity and programmed exercise: a crossover open-label study of five drug regimens. *J Am Coll Cardiol* **33:** 304–10
Fetsch T, Bauer P, Engberding R et al (2004) Prevention of atrial fibrillation after cardioversion: results of the PAFAC trial. *Eur Heart J* **25:** 1385–94
Fuster V, Ryden LE, Asinger RV et al (2001) ACC/AHA/ESC guidelines for the management of patients with atrial fibrillation. Task Force Report. *Circulation* **104:** 2118–50
Galve E, Rius T, Ballester R et al (1996) Intravenous amiodarone in treatment of recent-onset atrial fibrillation: results of a randomized, controlled study. *J Am Coll Cardiol* **27:** 1079–82
Haissaguerre M, Jais P, Shah DC et al (2000a) Electrophysiological end point for catheter ablation of atrial fibrillation initiated from multiple pulmonary venous foci. *Circulation* **101:** 1409–17
Haissaguerre M, Shah DC, Jais P et al (2000b) Electrophysiological breakthroughs from the left atrium to the pulmonary veins. *Circulation* **102:** 2463–5
Joglar JA, Hamdan MH, Ramaswamy K et al (2000) Initial energy for elective external cardioversion of persistent atrial fibrillation. *Am J Cardiol* **86:** 348–50
Kochiadakis GE, Igoumenidis NE, Solomou MC et al (1999) Efficacy of amiodarone for the termination of persistent atrial fibrillation. *Am J Cardiol* **83:** 58–61
Leitch JW, Klein G, Yee R et al (1991) Sinus node-atrioventricular node isolation: long-term results with the 'corridor' operation for atrial fibrillation. *J Am Coll Cardiol* **17:** 970–5
Levy S, Lacombe P, Cointe R et al (1988) High energy transcatheter cardioversion of chronic atrial fibrillation. *J Am Coll Cardiol* **12:** 514–18
Levy S, Ricard P, Gueunoun M et al (1997) Low-energy cardioversion of spontaneous atrial fibrillation: immediate and long-term results. *Circulation* **96:** 253–9
Lewis RV, McMurray J, McDevitt DG (1989) Effects of atenolol, verapamil, and xamoterol on heart rate and exercise tolerance in digitalised patients with chronic atrial fibrillation. *J Cardiovasc Pharmacol* **13:** 1–6
Lund M, French JK, Johnson RN et al (2000) Serum troponins T and I after elective cardioversion. *Eur Heart J* **21:** 245–53
Lundstrom T, Ryden L (1988) Chronic atrial fibrillation: long-term results of direct current conversion. *Acta Med Scand* **223:** 53–9
Natale A, Pisano E, Shewchik J et al (2000) First human experience with pulmonary vein isolation using a through-the-balloon circumferential ultrasound ablation system for recurrent atrial fibrillation. *Circulation* **102:** 1879–82
Pappone C, Rosanio S, Oreto G et al (2000) Circumferential radiofrequency ablation of pulmonary vein ostia: a new anatomic approach for curing atrial fibrillation. *Circulation* **102:** 2619–28
Pappone C, Oreto G, Rosanio S et al (2001) Atrial electroanatomical remodeling after circumferential radiofrequency pulmonary vein ablation: efficacy of an anatomic approach in a large cohort of patients with atrial fibrillation. *Circulation* **104:** 2539–44
Pietersen AH, Hellemann H (1991) Usefulness of flecanide for prevention of paroxysmal atrial fibrillation and flutter. *Am J Cardiol* **67:** 713–17
Roberts SA, Diaz C, Nolan PE et al (1993) Effectiveness and costs of digoxin treatment for atrial fibrillation and flutter. *Am J Cardiol* **72:** 567–73
Roy D, Talajic M, Dorian P et al for the Canadian Trial of Atrial Fibrillation Investigators (2000) Amiodarone to prevent recurrence of atrial fibrillation. *N Engl J Med* **342:** 913–20
Segal JB, McNamara RL, Miller MR et al (2000) The evidence regarding the drugs used for ventricular rate control. *J Fom Pract* **49:** 47–59
Shea JB, Maisel WH (2002) Cardioversion. *Circulation* **106**(22): e176–e178
Van Gelder IC, Crijns HJ, Van Gilst WH et al (1991) Prediction of uneventful cardioversion and maintenance of sinus rhythm from direct-current electrical cardioversion of chronic atrial fibrillation and flutter. *Am J Cardiol* **68:** 41–6
Van Gelder IC, Crijns HJ, Tieleman RG et al (1996) Chronic atrial fibrillation: success of serial cardioversion therapy and safety of oral anticoagulation. *Arch Intern Med* **156:** 2585–92
Van Gelder I, Haggens V, Bosker H et al (2002) A comparison of rate control and rhythm control in patients with recurrent persistent atrial fibrillation. *N Engl J Med* **347**(23): 1834–40
Van Hemel NM, Defaw JJAMT, Kingma JH et al (1994) Long-term results of the corridor operation for atrial fibrillation. *Br Heart J* **71:** 170–6
Vos MA, Golitsyn SR, Stangl K et al (1998) Superiority of ibutilide (a new class III agent) over dl-sotalol in converting atrial flutter and atrial fibrillation. *Heart* **79:** s68–75
Wood MA, Brown-Mahoney C, Kay GN et al (2000) Clinical outcomes after ablation and pacing therapy for atrial fibrillation: a meta-analysis. *Circulation* **101:** 1138–44
Wyse DG, Waldo AL, DiMarco JP et al (2002) A comparison of rate control and rhythm control in patients with atrial fibrillation. *N Engl J Med* **347**(23): v1825–33

KEY POINTS

- Antiarrhythmic drugs are most effective in restoring sinus rhythm if commenced within the first week of the onset of atrial fibrillation.
- Although electrical cardioversion is highly successful in converting atrial fibrillation to sinus rhythm, the rate of relapse is high if concomitant antiarrhythmic drugs are not given.
- Amiodarone is the most effective drug in maintaining sinus rhythm. However, because of its significant side effects it should not be used as first-line treatment.
- A rhythm control strategy offers no advantage over rate control with respect to survival.
- Pulmonary vein ablation is a relatively new technique that shows a high success rate in preventing atrial fibrillation.