

## REVIEW ARTICLE

# The peri-operative management of atrial fibrillation

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### Summary

Atrial fibrillation is a common arrhythmia frequently seen in surgical patients. The onset of new atrial fibrillation during the peri-operative period is less common. There are many possible precipitating factors, although volatile agents themselves may have an antifibrillatory action. The management of atrial fibrillation includes removal of any precipitating factors and treatment of the arrhythmia itself. Immediate management of acute-onset atrial fibrillation is usually direct current cardioversion. Alternatively, anti-arrhythmic drugs can be used to achieve cardioversion. In patients with rapid, chronic atrial fibrillation or those refractory to cardioversion, priority is given to control of the ventricular rate. Thrombo-embolism is a significant risk if atrial fibrillation is paroxysmal or persists for more than 48 h.

**Keywords** Heart; arrhythmia, atrial fibrillation, anti-arrhythmics.

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Atrial fibrillation is one of the most common of all cardiac arrhythmias. It may occur in a paroxysmal or a sustained form and is characterised by a very rapid (greater than 300 beats.min<sup>-1</sup>), irregular and disorganised depolarisation of the atria, inducing an irregular and often rapid ventricular response. The prevalence of atrial fibrillation is 0.4% in adults less than 60 years old and increases with age to 12% in those over 75 years [1]. It may therefore be seen coincidentally in many patients presenting for both elective and emergency anaesthesia. Alternatively, atrial fibrillation may occur for the first time during anaesthesia and surgery.

The aim of this review is to provide the practitioner with a review of the management of atrial fibrillation with particular emphasis on the management of peri-operative atrial fibrillation. Differentiation of atrial fibrillation from atrial flutter may be difficult and the differences in treatment of these two arrhythmias are highlighted. The review describes the clinical features and consequences of atrial fibrillation and discusses those precipitating factors that may be particularly relevant during anaesthesia, including the action of anaesthetic agents. As the onset of new atrial fibrillation is unusual

during anaesthesia, reports of treatment are mostly anecdotal. Recommendations in this review for the intra-operative management of acute onset atrial fibrillation and the control of chronic atrial fibrillation prior to anaesthesia are therefore based on trials involving general medical patients. However, because of the lack of well-conducted clinical trials, the treatment of acute atrial fibrillation in general medical and cardiological practice itself remains controversial [2]. One situation in which peri-operative arrhythmias are commonly seen and have been well studied is cardiac surgery. This specialist area has been the subject of reviews and meta-analyses and readers interested in this subject are referred to these articles for further information [3–5].

### Aetiology

Ischaemic heart disease is probably the most common cause of atrial fibrillation, followed by hypertension, rheumatic heart disease, thyrotoxicosis and pneumonia (Table 1).

During the peri-operative period, the onset of atrial fibrillation or faster rates of chronic atrial fibrillation

**Table 1** Aetiology of atrial fibrillation.

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Acid-base abnormalities
<b>Acute infections, especially pneumonia</b>
Alcohol intoxication
Atrial septal defect
Atrial or pericardial manipulation during cardiac surgery
Atrial myxoma
Bronchial carcinoma
Cardiomyopathy
Central venous catheters
Electroconvulsive therapy
Electrolyte abnormalities
<b>Hypertension</b>
Hypovolaemia
Hypoxia
<b>Myocardial ischaemia</b>
Pericardial disease
Pleural effusion
Post-pneumonectomy
Pre-excitation syndromes (e.g. Wolff–Parkinson–White Syndrome)
Pulmonary embolism
<b>Rheumatic heart disease</b>
Sick-sinus syndrome
Thyrotoxicosis

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The commonest causes are in **bold** typeface.

may be precipitated by acid–base disturbances, electrolyte abnormalities (in particular hypokalaemia or hypomagnesaemia [6]), hypovolaemia, myocardial ischaemia and surgical manipulation in the thorax. Although the development of arrhythmias is common during anaesthesia and surgery, the onset of atrial fibrillation or atrial flutter is unusual [7, 8]. Rogers *et al.* reported 50 patients with supraventricular tachyarrhythmias during or following surgery [9]. The overall incidence of supraventricular tachycardia (SVT) was estimated to be less than 1%. In those with an SVT, the incidence of atrial fibrillation and atrial flutter was 30% and 12%, respectively, only 20% of the arrhythmias occurring intra-operatively. Although this study was uncontrolled, the authors concluded that risk factors for development of an arrhythmia were procedures in the chest, intra-operative hypotension and postoperative cardiopulmonary complications [9].

### Anaesthetic agents

The action of volatile anaesthetic agents in sensitising the myocardium to catecholamines is well known [10]. However, volatile anaesthetics may also have an apparent antifibrillatory effect in the ventricle following periods of ischaemia and reperfusion similar to that of the calcium-channel blocking drugs, e.g. verapamil [11]. The effects of volatile agents on the atria are complex and include depression of sinus node automaticity, increased supraventricular refractoriness and depressed atrio-ventricular (A–V) nodal conduction [12–14]. These effects have differing and sometimes opposing actions as factors for

inducing and maintaining arrhythmias. However, drugs that increase the atrial refractory period usually have an antifibrillatory effect in the atria. Isoflurane has been shown to have an antifibrillatory action in canine atrial tissue [15]. Temporary conversion of chronic atrial fibrillation to sinus rhythm during anaesthesia has also been reported [16]. Sympathetic stimulation or a vagolytic effect may increase the ventricular rate during atrial fibrillation. These effects may be due to the anaesthetic drugs themselves, e.g. pancuronium [17]. Atrial fibrillation may also be induced by the procedure for which general anaesthesia is being given, e.g. electroconvulsive therapy, which causes vagal and sympathetic stimulation [18].

### Clinical features

Atrial fibrillation results in a pulse which is completely irregular ('irregularly irregular'). The irregularity is usually obvious when the ventricular rate is rapid but is less easy to recognise when the rate has been slowed. There are no 'a' waves visible in the jugular venous pulse and the 'x' descent is obliterated because there is no significant atrial relaxation. Atrial flutter may produce enough atrial activity to produce rapid 'a' waves in the jugular venous pulse. Other physical signs of atrial fibrillation include a variation in the intensity of the first heart sound and a difference between the pulse rate measured at the apex and the wrist. This difference is more marked with rapid ventricular rates. Carotid sinus massage usually has little effect in atrial fibrillation but will slow the ventricular rate in atrial flutter. This effect results from increased A–V block and usually lasts only as long as the carotid sinus massage is continued, although it occasionally results in a return to sinus rhythm.

### Electrocardiogram features

During atrial fibrillation the electrocardiogram (ECG) demonstrates the rapid and chaotic atrial activity with deflections which are irregular in both size and rate but without visible P waves. These deflections, sometimes known as 'f' waves, may not be seen in all leads. They are best seen in lead V<sub>1</sub> and may also be seen in leads II, III and aVF. The result is sometimes known as a 'ragged baseline'. In long-standing atrial fibrillation, the atrial activity may be of low amplitude and the baseline becomes straight [19]. The ECG also demonstrates the irregular ventricular response. Bundle branch block may be seen in some ventricular complexes and its presence may vary from beat to beat. The resulting complexes may be difficult to distinguish from ventricular ectopics. This effect, known as the Ashman phenomenon [20], results from phasic aberrant ventricular conduction due to unequal

refractory periods of the bundle branches. It is usually seen when a long ventricular cycle is immediately followed by a short cycle.

Atrial flutter is characterised by rapid and regular atrial activity with a rate between 250 and 350 beats.min<sup>-1</sup>. This activity is seen on the ECG as flutter or 'F' waves. These waves are regular and closely spaced together but each complex is relatively wide. The result is a saw-tooth patterned baseline best seen in standard lead II and lead V<sub>1</sub>. The ventricular response again depends on the efficiency of the A-V node, which may transmit all of the atrial waves, leading to a dangerously fast ventricular response. However, there is usually second degree A-V block with a conduction ratio of atrial waves to transmitted waves of between 2 : 1 and 8 : 1. The ratio may vary rapidly, leading to an irregular ventricular rate and phasic aberrant ventricular conduction.

During surgery, when access to the patient is reduced and it is not easy to perform the standard 12-lead ECG, other methods of monitoring the electrical activity of the heart are used. The usual arrangement for ECG leads during anaesthesia is a bipolar system. The optimal lead for detecting and identifying arrhythmias is standard lead II. However, more specific techniques for assessing atrial electrical activity have been used. The guide wire of a right atrial catheter may be left in place with its end protruding from the tip of the catheter and this may be used to monitor activity from the right atrium directly [21]. An insulated guide wire placed in the oesophagus or electrodes attached to an oesophageal stethoscope can be positioned behind the left atrium by observing for the point of maximum P wave amplitude as the device is passed down the oesophagus [22, 23]. Such an oesophageal lead, used in a small study of cardiac surgery patients, enabled correct identification of all intra-operative arrhythmias [23]. Although unlikely to be adopted as part of routine intra-operative monitoring, these techniques may have a role in high-risk patients. It is essential for such devices to be used with equipment designed to prevent electrical microshock.

### Clinical consequences

The adverse effects of atrial fibrillation include:

- 1 loss of the atrial component to diastole;
- 2 excessively rapid ventricular rate;
- 3 systemic thrombo-embolism and a significant risk of stroke;
- 4 patient discomfort due to palpitations.

The effect of atrial fibrillation on cardiovascular function depends on a number of factors, the most important of which is pre-existing cardiac status. The loss of atrial contraction may lead to a decrease in cardiac output and

blood pressure of up to 50% [24]. At rest, atrial systole has little effect on basal cardiac output [25], although with increasing age atrial systole may have more importance [26]. A heart with impaired left ventricular function may depend more on atrial systole, although the 'atrial kick' has a smaller effect on cardiac output when left ventricular end-diastolic pressure is high [27]. The importance of the lack of atrial activity in patients with atrial fibrillation may only be apparent during exercise [24]. The irregularity of the ventricular rhythm itself does not lead to significant cardiovascular effects [1].

Chronic tachycardia may lead to an impairment of left ventricular function that is improved after control of the rate or cardioversion to sinus rhythm [28]. If atrial fibrillation becomes chronic, the ventricular rate must be controlled so as to increase diastolic filling time. However, a higher ventricular rate than normal is required to compensate for the loss of effective atrial contraction. The optimum ventricular rate at rest has been shown to be 90 beats.min<sup>-1</sup>, with faster rates being appropriate during exercise [29]. Haemodynamic studies have demonstrated decreased right and left atrial pressures, increased cardiac output at rest and during exercise and an increased capacity for exercise following successful cardioversion [24, 30–34]. Although atrial electrical activity returns immediately after successful cardioversion, the improvement in atrial mechanical function is variable and usually increases over the subsequent 24 h [35, 36]. The maximum improvement in atrial function may take up to 3 weeks to achieve after cardioversion [37] but is more rapid after conversion of atrial fibrillation of short duration [36].

### Treatment

Many trials of drug therapy for acute atrial fibrillation are uncontrolled and as up to 50% of cases of recent-onset atrial fibrillation revert spontaneously to sinus rhythm, these studies are difficult to interpret [1]. Anti-arrhythmic agents are usually classified using the Vaughan Williams system [38], based on their electrophysiological properties (Table 2). Direct current (DC) cardioversion remains the best method for managing acute-onset atrial fibrillation.

#### Direct current cardioversion

Direct current cardioversion was first introduced for the management of atrial fibrillation in 1962 [39]. Early studies reported a success rate of ≈ 90%, with few complications [40, 41]. Direct current cardioversion acts rapidly, is highly effective and avoids the potential complications of drug therapy. However, it requires general anaesthesia [42]. To avoid inducing ventricular fibrillation, the timing of the electrical shock is synchronised with the QRS complex. The electrical current causes a generalised

**Table 2** Classification of antiarrhythmic agents used in the management of atrial fibrillation (after Vaughan Williams [38]).

Class	Action	Drugs
Ia	Membrane-stabilizing	Procainamide Quinidine Disopyramide
Ic	Membrane-stabilizing	Flecainide Propafenone
II	$\beta$ -adrenoceptor blockers	Esmolol Propranolol
III	Action potential prolongation	Amiodarone Sotalol
IV	Calcium channel antagonist	Verapamil Diltiazem
Others	Cardiac glycosides	Digoxin

depolarisation of all excitable myocardium. Circuits sustaining re-entry within the atria are disrupted and during the ensuing period of asystole, the sinus node is able to resume its role as the pacemaker. However, the arrhythmia may resume if precipitating factors are not corrected. Direct current cardioversion should not be performed if the patient has digoxin levels above the therapeutic range. The energy requirements are usually in the 25–100 J range but occasionally higher energy shocks (200 J) are required, particularly if the duration of the atrial fibrillation is less than 24 h [43]. Left atrial size is not a predictor of successful cardioversion. However, the success rate is greater with arrhythmias of short duration [43–45]. Prior treatment with class Ia anti-arrhythmic drugs such as quinidine or disopyramide may increase the success rate [46]. ST segment changes following cardioversion occur in up to 19% of patients, particularly in those patients who have undergone cardiac surgery [47]. However, there is no evidence of myocardial damage and cardiac enzymes are usually normal after DC cardioversion.

#### Class Ia agents – membrane stabilisers

These drugs work by blocking fast sodium channels, reducing the velocity of the upstroke of the action potential and slowing the conduction of the impulse through the myocardium. They prolong myocardial refractoriness and extend the repolarisation time.

*Procainamide.* Procainamide is negatively inotropic, especially in patients with left ventricular dysfunction, and may also cause conduction disturbances. It has been used to convert atrial fibrillation for over 40 years [48]. In two uncontrolled studies, an intravenous infusion of procainamide was effective in restoring sinus rhythm in

43% and 58% of patients [49, 50]. The conversion rate is increased in patients with atrial fibrillation of recent onset [49]. However, procainamide is less effective than the class Ic drugs [51].

*Quinidine.* Oral quinidine is effective in converting atrial fibrillation to sinus rhythm [1]. However, administering the drug orally is time consuming and the patient must be monitored continuously. Side-effects include ventricular tachycardia, quinidine syncope, blood dyscrasias and cinchonism. As a result, many patients have to discontinue the drug during long-term use. Pilati *et al.* reported a conversion rate of 92% for patients with recent onset atrial fibrillation treated with oral quinidine [52]. However, the time to conversion was nearly 8 h. Quinidine is often used, especially in North America, for maintaining sinus rhythm after cardioversion or for reducing the frequency of paroxysmal atrial fibrillation [53]. A meta-analysis has suggested an excess mortality in patients receiving long-term quinidine therapy for maintenance of sinus rhythm [54] and its role in the management of paroxysmal atrial fibrillation is therefore unclear. Other drugs may be equally effective but have fewer side-effects [55].

*Disopyramide.* Intravenous disopyramide is associated with a marked reduction in myocardial contractility and the potential for A-V block. It is not usually used for cardioversion but may be used to prevent recurrences of atrial fibrillation after successful cardioversion [56]. Disopyramide is poorly tolerated because of its anticholinergic effects, particularly in elderly patients and those with glaucoma or prostatism.

#### Class Ic agents – membrane stabilisers

These drugs act on sodium channels to slow the upstroke of the action potential and prolong conduction.

*Flecainide.* An overview of clinical trials found that intravenous flecainide was effective in converting 62% of cases of recent-onset atrial fibrillation to sinus rhythm [57]. The overall incidence of adverse events was low (3.7%) and included worsening arrhythmias, conduction abnormalities and heart failure. Flecainide has negative inotropic actions and should be avoided in patients with significant impairment of left ventricular function. It is less effective in converting chronic atrial fibrillation and atrial flutter [58, 59]. Flecainide may reduce A-V block in patients with atrial flutter resulting in a 1:1 conduction ratio and a dangerously fast ventricular rate. Studies have suggested the superior efficacy of flecainide over verapamil [60], amiodarone [61] and procainamide [51]. In a direct comparison with propafenone, flecainide was

more effective at converting atrial fibrillation to sinus rhythm (93% vs. 57%, respectively), although the incidence of side-effects was higher in the group receiving flecainide [62].

Flecainide may be used to maintain sinus rhythm in patients with paroxysmal atrial fibrillation. However, concerns about the safety of long-term flecainide therapy have been raised by the Cardiac Arrhythmia Suppression Trial, in which patients with previous myocardial infarction treated with flecainide for ventricular arrhythmias had an increased mortality [63]. The prognosis for patients with atrial arrhythmias may be more favourable, particularly if structural or ischaemic heart disease is not present [64]. The long-term use of class Ic drugs such as flecainide to treat paroxysmal atrial fibrillation should be limited to patients refractory to other therapy [65].

*Propafenone.* Propafenone is a class Ic anti-arrhythmic agent and also has clinically significant  $\beta$ -adrenoceptor blocking activity [64]. Bianconi *et al.* reported that intravenous propafenone converted 71% of patients with atrial fibrillation of less than 48 h duration in a mean of 29 min [66]. Propafenone is more effective than amiodarone but less effective than flecainide [62, 67]. Propafenone is much less effective in converting chronic atrial fibrillation [68]. Oral propafenone can be used to reduce the frequency of episodes of paroxysmal atrial fibrillation [69]. However, concerns about the long-term use of class Ic agents limit its use (see flecainide). The intravenous preparation of propafenone is not available in the UK.

### Class II agents – $\beta$ -adrenoceptor blockers

Most studies show that  $\beta$ -adrenergic receptor blocking agents ( $\beta$ -blockers) are ineffective in terminating atrial fibrillation [70, 71]. However, these drugs are effective in controlling the ventricular rate and may be used alone or in combination with digoxin.  $\beta$ -blockers may be the agent of first choice in hyperadrenergic states, e.g. thyrotoxicosis. Negative inotropic effects may limit their use.

*Esmolol.* Esmolol is an ultrashort-acting cardioselective  $\beta_1$ -blocking agent. Its elimination half-time is 9 min, due to rapid degradation by red blood cell esterases. In a small study, Platia *et al.* compared the efficacy of esmolol and verapamil in the management of atrial fibrillation and found that the reduction in ventricular rate and the incidence of hypotension were similar [72]. Hypotension is a common side-effect of treatment with esmolol but is usually well tolerated and responds to discontinuation of the drug [71] and administration of intravenous fluids. Because the dose of esmolol can be titrated according to the ventricular rate, it may be particularly useful in

rapidly changing situations. In the majority of patients, the therapeutic response is lost within 30 min of stopping the esmolol infusion [71].

### Class III agents – action potential prolongation

These drugs have a number of actions including blockage of outward potassium currents. They lengthen the action potential, prolong repolarisation and increase atrial refractoriness. They lengthen the QT interval.

*Amiodarone.* Amiodarone is a class III agent but also slows A-V node conduction and has class I type actions [1, 73]. Amiodarone can convert atrial fibrillation to sinus rhythm, probably by prolonging both the action potential and the atrial refractory period. One study found that all patients with acute-onset atrial fibrillation converted to sinus rhythm after amiodarone [52]. However, others have found amiodarone to be only partially effective [74, 75]. Faniel and Schoenfeld experimented with a variety of dose regimens of amiodarone in 26 patients with acute atrial fibrillation [74]. Eighty-one per cent converted to sinus rhythm within 24 h and the mean total dose of amiodarone in the converters was  $6.9 \text{ mg} \cdot \text{kg}^{-1}$ . Intravenous amiodarone may cause venous sclerosis when given peripherally and administration through a central line is therefore recommended. Chronic oral administration of amiodarone may be useful in maintaining sinus rhythm and controlling the ventricular response in patients with atrial fibrillation refractory to other agents, although the high incidence of adverse events may lead to withdrawal of therapy in some patients [76]. A recent review found that amiodarone may be the best drug for the maintenance of sinus rhythm after conversion from atrial fibrillation [1].

Serious interactions between chronic amiodarone therapy and general anaesthesia have been reported [77]. These include bradyarrhythmias in noncardiac patients and both low cardiac output states and high cardiac output states with a low systemic vascular resistance after cardiopulmonary bypass. These may be due to the non-competitive anti-adrenergic effects of amiodarone [77]. Hypotension during acute administration of amiodarone usually responds to volume expansion or a decrease in the infusion rate [73]. There is a poorly understood relationship between chronic oral amiodarone administration to patients and the adult respiratory distress syndrome (ARDS), particularly after cardiopulmonary bypass or thoracic surgery [73]. The clinical implications of these reports for the use of intravenous amiodarone during anaesthesia are unknown.

*Sotalol.* Sotalol combines class III properties with a  $\beta$ -blocking action (class II) [78]. The conversion rate of

acute atrial fibrillation to sinus rhythm with sotalol is low and is less than with class Ia or Ic agents [79–81]. Patients not converting to sinus rhythm with sotalol usually have a reduced ventricular response [79, 81]. Sotalol may be used as an alternative to quinidine for maintenance of sinus rhythm after DC cardioversion of chronic atrial fibrillation and is better tolerated [55]. Sotalol, like all other anti-arrhythmic agents, is also pro-arrhythmic. In particular, chronic use of sotalol has been linked with the development of a prolonged QT interval and torsades de pointes [82]. Hypokalaemia may be an important predisposing factor and concurrent administration with diuretics should be avoided [82].

#### Class IV agents – calcium channel blockers

Calcium channel blockers (or calcium antagonists) block the inward movement of calcium in the cells of the conduction system and so reduce automaticity, conduction velocity and increase the refractory period. In particular, they act on the A–V node to slow conduction.

*Verapamil.* Conversion of atrial fibrillation to sinus rhythm using verapamil is generally poor (8–37%) [72, 83–86]. Amiodarone, esmolol and flecainide are all more effective than verapamil in converting recent onset atrial fibrillation to sinus rhythm [60, 72, 87]. However, verapamil is effective in slowing the ventricular rate [83–86, 88–90].

Verapamil may increase conduction along anomalous pathways and should not be used in Wolff–Parkinson–White syndrome. Vohra *et al.* reported that verapamil 10 mg given to patients with controlled atrial fibrillation produced no change in cardiac output or systemic vascular resistance [91]. A decrease in heart rate was compensated for by an increase in stroke volume. Rydén and Saetre studied two digitalised patients with atrial fibrillation and found that a similar dose of verapamil resulted in a decrease in heart rate which was not fully compensated by the increase in stroke volume leading to decreases in cardiac output (19%) and blood pressure [92]. Esmolol may also be preferred to verapamil because of its rapid clearance from the circulation if bradycardia or hypotension develop [93]. Verapamil should not be combined with a  $\beta$ -blocking agent as the effect on conduction and myocardial contraction is additive.

*Diltiazem.* Compared with verapamil, diltiazem has relatively mild negative inotropic effects [94]. It provides effective control of the ventricular response in atrial fibrillation but does not promote conversion to sinus rhythm [95]. In a study of patients with atrial fibrillation and atrial flutter, intravenous diltiazem successfully controlled the ventricular rate in over 90% of patients. The

mean time to the maximal decrease in heart rate was 4.3 min and the mean decrease in systolic blood pressure was 8%. A disadvantage of diltiazem is its relatively short duration of action. Heart rate control rarely lasts longer than 2 h [94]. Infusions of diltiazem may be used for more prolonged control of heart rate [96], although intravenous diltiazem is not available in the UK. Oral diltiazem may be used to control heart rate in chronic atrial fibrillation without reducing exercise capacity [97]. The combination of diltiazem and digoxin may result in improved control of heart rate at rest and during exercise compared with either drug given alone [98].

#### Digoxin

Digoxin acts by inhibiting potassium/sodium-dependent adenosine triphosphatase. It slows the ventricular response by enhancing vagal effects on the A–V node, slowing A–V nodal conduction and increasing A–V nodal refractoriness. Digoxin also has a mild positive inotropic effect that is beneficial in those patients with left ventricular impairment. In situations where sympathetic tone is high, such as thyrotoxicosis, sepsis, exercise and hyperadrenergic states, digoxin is relatively ineffective in controlling the ventricular response and an alternative drug should be considered. Control of the ventricular rate is achieved relatively slowly, often several hours after the start of treatment. In an uncontrolled study, Weiner *et al.* found that digoxin resulted in conversion to sinus rhythm in a large proportion of patients with recent-onset atrial fibrillation [99]. However, as with other similar studies, interpretation of the results is difficult because of the high rate of spontaneous conversion. Falk *et al.* found no difference between digoxin and placebo [100]. Prophylactic pre-operative digitalisation for patients likely to develop atrial fibrillation, including those undergoing cardiac and thoracic surgery, was recommended nearly 30 years ago [101]. Prophylactic digoxin decreases the incidence and severity of atrial fibrillation and other arrhythmias after thoracic surgery [102]. Because of its low cost, positive inotropic action and long half-life, digoxin is the drug of first choice for long-term rate control of patients with chronic atrial fibrillation which is not paroxysmal or associated with a hyperadrenergic state [2]. It is often combined with either a  $\beta$ -blocker or calcium channel blocker in order to improve rate control, particularly during exercise.

#### Management strategies

The treatment of atrial fibrillation can be divided into:

- 1 management of acute-onset atrial fibrillation;
- 2 maintenance of sinus rhythm;
- 3 control of ventricular rate;
- 4 prevention of thromboembolism.

**Table 3** Drugs used for pharmacological cardioversion of atrial fibrillation to sinus rhythm.

Drug	Dose (adult)	Comments/side-effects
Procainamide	100 mg (at 50 mg.min <sup>-1</sup> ), repeated every 5 min, max 1 g	Conduction defects, hypotension, gastro-intestinal symptoms. Not licensed in the UK for this indication
Quinidine	200–400 mg, 6–8 hly, orally (Slow release 500 mg, 12 hly)	Slow onset. Arrhythmias, gastro-intestinal symptoms, blood dyscrasias, hepatitis
Disopyramide	2 mg.kg <sup>-1</sup> over 5 min, max 150 mg	Conduction defects, myocardial depression, anticholinergic effects
Flecainide	2 mg.kg <sup>-1</sup> over 10–30 min, max 150 mg	Arrhythmias, myocardial depression
Propafenone	2 mg.kg <sup>-1</sup> over 10–20 min	Myocardial depression. Intravenous preparation not available in the UK
Amiodarone	5 mg.kg <sup>-1</sup> over 20–120 min, then 15 mg.kg <sup>-1</sup> (max 1.2 g) over 24 h.	Anaphylaxis, circulatory collapse
Sotalol	20–120 mg over 10 min	Bradycardia, hypotension

### Management of acute-onset atrial fibrillation

The immediate management of acute-onset atrial fibrillation is usually cardioversion to sinus rhythm. The most reliable method is DC cardioversion. The main disadvantage of the technique is the requirement for general anaesthesia in a patient who may be otherwise unstable. However, this is not a factor in patients who are already anaesthetised and who develop atrial fibrillation. In this situation DC cardioversion is the treatment of choice. Precipitating factors must be identified and corrected and such treatment may lead to spontaneous conversion to sinus rhythm. The most likely causes include myocardial ischaemia, electrolyte abnormalities and surgical manipulation within the thorax or mediastinum. The early reports of DC cardioversion noted that the technique was of use in patients with acute cardiovascular decompensation [41] and it remains the most rapid method for restoring sinus rhythm in a patient who is cardiovascularly compromised. Indications for urgent DC cardioversion include atrial fibrillation associated with hypotension, congestive cardiac failure, active ischaemia or acute infarction and patients with severe aortic stenosis, mitral stenosis and hypertrophic cardiomyopathy [103]. Contraindications include digoxin toxicity, a history of bradycardia or sick sinus syndrome and inadequately treated precipitating cause [103]. Direct current cardioversion should not be used in atrial fibrillation of more than 48 h duration without at least 3 weeks of anticoagulation (see below).

Acute atrial flutter is usually unresponsive to pharmacological therapy and is best managed by DC cardioversion, which usually results in sinus rhythm or in atrial fibrillation when the ventricular rate can be controlled with the usual agents. Class Ia and Ic drugs may reduce the degree of A-V block and lead to 1:1 conduction and dangerously high ventricular rates. They should only be used in atrial flutter after conduction through the A-V node has been slowed with digoxin, a  $\beta$ -adrenoceptor blocker or a calcium channel blocker.

The role of pharmacological cardioversion in the

management of acute atrial fibrillation is not clear. In the general medical population, pharmacological cardioversion may be used as the first treatment, particularly in those patients unsuitable for DC cardioversion or general anaesthesia. However, its role in the peri-operative period, particularly for the treatment of atrial fibrillation of acute onset during the course of an anaesthetic, has not been studied. Drugs that act to lengthen the atrial refractory period may terminate the arrhythmia. Therefore, class Ia, Ic and III agents are used (Table 3). In terms of speed of action and conversion rate, the most useful drugs are probably flecainide and amiodarone.

### Maintenance of sinus rhythm

Prophylactic treatment to prevent recurrences of atrial fibrillation requires consideration of the risk:benefit ratio. Class Ia, Ic and III agents are used (Table 4). In general, these agents are effective in maintaining sinus rhythm in about 50–70% of cases. The anaesthetist will not usually be involved with the initiation or control of such therapy. However, all these drugs have side-effects, including pro-arrhythmic actions, of which the anaesthetist should be aware. In particular, chronic therapy with amiodarone is associated with cardiovascular disturbance during general anaesthesia and pulmonary dysfunction following some surgical procedures (see class III agents – amiodarone).

### Control of ventricular rate

The optimum ventricular rate in patients with chronic atrial fibrillation is 90 beats.min<sup>-1</sup>. In some patients, particularly the elderly, the rate is inherently slow without drug therapy. However, long-term oral therapy to control the ventricular rate is usually required in those patients in whom restoration of sinus rhythm is either impossible or who rapidly revert to atrial fibrillation. Despite numerous side-effects, digoxin remains the most popular drug, probably because of its mild positive inotropic action [2, 104]. In long-term use, digoxin is often combined

**Table 4** Drugs used to maintain sinus rhythm.

Drug	Dose (adult)	Comments/side-effects
Quinidine	200–400 mg, 6–8 hly, orally (Slow release 500 mg, 12 hly)	Arrhythmias, gastro-intestinal symptoms, blood dyscrasias, hepatitis
Disopyramide	100–200 mg, 6–8 hly, orally	Conduction defects, gastro-intestinal symptoms, anticholinergic effects
Flecainide	50–150 mg, 12 hly, orally	Arrhythmias, gastro-intestinal and central nervous system symptoms
Propafenone	150–300 mg, 8 hly, orally (Reduce dose if < 70 kg body weight)	Arrhythmias, conduction defects, heart failure, gastro-intestinal symptoms
Amiodarone	200–300 mg, once daily, orally	Conduction defects, corneal microdeposits, neuropathy, pulmonary fibrosis, hepatitis, photosensitivity, hyperthyroidism and hypothyroidism, interaction with general anaesthesia
Sotalol	40–160 mg, 12 hly, orally	Arrhythmias

with a calcium channel blocker or, less frequently, a  $\beta$ -blocker. Patients whose heart rate increases during the peri-operative period or those whose atrial fibrillation which proves refractory to conversion may require more urgent control of the ventricular rate (Table 5). The most useful agents are intravenous verapamil or esmolol. Both drugs have a negative inotropic action but the short elimination half-life of esmolol allows easy manipulation of plasma levels. Amiodarone is an alternative for the acute control of ventricular rate and has the advantage that it may also bring about chemical conversion to sinus rhythm.

#### Prevention of thrombo-embolism

Atrial stasis caused by atrial fibrillation promotes clot formation. The most significant risk is thrombo-embolic stroke. The overall risk of stroke in patients with chronic atrial fibrillation is 5% per year [1]. Recent randomised, controlled trials have confirmed that oral anticoagulation with warfarin reduces the risk of stroke [1, 105]. Most patients with chronic or paroxysmal atrial fibrillation will be anticoagulated unless they have a contraindication such as gastrointestinal bleeding or severe hypertension. The risks associated with stopping warfarin during the peri-operative period are unknown.

By restoring mechanical function to the atria, cardioversion can promote clot dislodgement and thrombo-embolism. The risk of systemic embolisation after DC cardioversion in nonanticoagulated patients with atrial fibrillation is about 5% [106]. Anticoagulation reduces the incidence of embolisation to about 1% [106, 107]. In the elective situation, where atrial fibrillation has been present for more than 48 h, cardioversion should be delayed to allow 3–4 weeks of oral anticoagulation [93, 107]. Anticoagulation should be continued for at least 4 weeks after cardioversion [108]. The use of transoesophageal echocardiography (which is more sensitive than standard transthoracic echocardiography in detecting left atrial thrombi) to identify those patients without atrial thrombi and thus permit early cardioversion without anticoagulation has been proposed, although a recent analysis of pooled results did not support this practice [109, 110].

#### Further investigation and treatment of atrial fibrillation

Atrial fibrillation which is newly diagnosed in the peri-operative period and is not associated with known precipitating factors warrants full investigation (Table 6).

**Table 5** Drugs used for acute control of ventricular rate in atrial fibrillation.

Drug	Dose (adult)	Comments/side-effects
Esmolol	Bolus: 500 $\mu\text{g}\cdot\text{kg}^{-1}$ over 1 min Maintenance: 50–200 $\mu\text{g}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Repeat bolus every 5 min if necessary)	Hypotension, avoid combinations with calcium-channel blockers
Propranolol	Bolus: 1 mg every 2 min to max 5 mg	As above but longer duration of action
Verapamil	Bolus: 5–10 mg over 2 min Further 5 mg after 5–10 min if necessary	Hypotension, avoid combinations with $\beta$ -blockers. Avoid in Wolff–Parkinson–White syndrome
Diltiazem	Bolus: 0.25 $\text{mg}\cdot\text{kg}^{-1}$ over 2 min Repeat bolus after 15 min if necessary Maintenance: 5–15 $\text{mg}\cdot\text{h}^{-1}$	As for verapamil. Intravenous preparation not available in the UK
Digoxin	Bolus: 250–500 $\mu\text{g}$ over 10–20 min Further doses every 4–8 h to max 1.0 mg over first 24 h	Slow onset. Ineffective in hyperadrenergic states. Avoid in Wolff–Parkinson–White syndrome



**Table 6** Investigation of atrial fibrillation.

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- Full history and examination.
  - 12 lead ECG (including an ECG during periods of sinus rhythm if atrial fibrillation is paroxysmal in order to detect intra-atrial conduction defects).
  - Echocardiography (for diagnosis and to identify patients with impaired left ventricular function in whom negatively inotropic agents should be avoided).
  - Serum chemistry screen including thyroid function tests.
  - Exercise ECG if the arrhythmia is exercise-induced.
  - Electrophysiological studies in patients who are young or refractory to treatment.
- 

Patients with persistent or recurrent atrial fibrillation will need consideration for long-term therapy. This will usually be initiated by a physician or cardiologist.

The anaesthetist may see patients who have proved refractory to therapy and have undergone radiofrequency catheter ablation of the A-V conduction pathway [111]. Some of these patients, and also those who have an excessively slow ventricular rate, will be fitted with permanent pacemakers and the usual precautions during anaesthesia are required.

## Conclusion

The management of peri-operative atrial fibrillation is based on knowledge gained from nonanaesthetised medical patients. However, factors relevant to the peri-operative period, particularly the occurrence of acute precipitating factors, must be borne in mind and dealt with. With the use of simple algorithms and knowledge of a relatively small number of drugs and DC cardioversion therapy, the anaesthetist should be able to manage atrial fibrillation safely and effectively.

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