

Atrial Fibrillation after Cardiac Surgery

William H. Maisel, MD, MPH; James D. Rawn, MD; and William G. Stevenson, MD

Purpose: To review the epidemiology, mechanisms, complications, predictors, prevention, and treatment of atrial fibrillation following cardiac surgery.

Data Sources: MEDLINE search of English-language reports published between 1966 and 2000 and a search of references of relevant papers.

Study Selection: Clinical and basic research studies on atrial fibrillation after cardiac surgery.

Data Extraction: Relevant clinical information was extracted from selected articles.

Data Synthesis: Atrial fibrillation occurs in 10% to 65% of patients after cardiac surgery, usually on the second or third postoperative day. Postoperative atrial fibrillation is associated with increased morbidity and mortality and longer, more expensive hospital stays. Prophylactic use of β -adrenergic blockers reduces the incidence of postoperative atrial fibrillation and should be administered before and after cardiac surgery to all patients without contraindication. Prophylactic amiodarone and atrial overdrive

pacings should be considered in patients at high risk for postoperative atrial fibrillation (for example, patients with previous atrial fibrillation or mitral valve surgery).

For patients who develop atrial fibrillation after cardiac surgery, a strategy of rhythm management or rate management should be selected. For patients who are hemodynamically unstable or highly symptomatic or who have a contraindication to anticoagulation, rhythm management with electrical cardioversion, amiodarone, or both is preferred. Treatment of the remaining patients should focus on rate control because most will spontaneously revert to sinus rhythm within 6 weeks after discharge. All patients with atrial fibrillation persisting for more than 24 to 48 hours and without contraindication should receive anticoagulation.

Conclusions: Atrial fibrillation frequently complicates cardiac surgery. Many cases can be prevented with appropriate prophylactic therapy. A strategy of rhythm management for symptomatic patients and rate management for all other patients usually results in reversion to sinus rhythm within 6 weeks of discharge.

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For author affiliations and current addresses, see end of text.

More than 200 000 patients undergo coronary artery bypass grafting (CABG) annually worldwide (1). Atrial fibrillation frequently occurs after cardiac surgery and has enormous cost implications (2-4). Management of atrial fibrillation in this setting is often frustrating, and strategies vary widely from institution to institution.

METHODS

We searched the MEDLINE database for English-language reports published between 1966 and June 2000 by using the keywords *atrial fibrillation*, *arrhythmia*, *coronary artery bypass*, *anti-arrhythmic agents*, *electrical countershock*, *anticoagulation*, and *complications*. In addition, we searched references from relevant articles. Research studies relating to the epidemiology, mechanisms, complications, predictors, prevention, or treatment of atrial fibrillation after cardiac surgery were reviewed and relevant clinical information was extracted. Few articles from 1966 to 1979 are cited because the scientific methods of reports from this period were not well described or were not rigorous or because the reports seemed irrelevant to our current understanding of atrial fibrillation.

EPIDEMIOLOGY

Atrial arrhythmias occur after cardiac surgery in 10% to 65% of patients (2, 3, 5-25), depending on patient profile, type of surgery, method of arrhythmia surveillance, and definition of arrhythmia (Table 1). A meta-analysis of 24 trials (5) estimated the incidence at 26.7%. Patients undergoing CABG alone have a lower incidence of postoperative atrial fibrillation than patients undergoing valve surgery or combined CABG-valve operations (6, 11) (Table 1). Although the number of patients undergoing heart transplantation is relatively small, these patients appear to have the lowest incidence of postoperative atrial fibrillation (11). The highest incidence of atrial fibrillation is seen on postoperative days 2 to 3, with fewer patients developing atrial fibrillation either in the early postoperative period or 4 or more days after surgery (2, 9, 15, 19, 26).

MECHANISMS OF ATRIAL FIBRILLATION AFTER CARDIAC SURGERY

Atrial fibrillation is usually attributed to reentry of multiple wavelets of excitation circulating throughout the atria. The exact electrophysiologic mechanisms caus-

Table 1. Atrial Arrhythmias after Cardiac Surgery in Studies Involving ≥ 500 Patients: Incidence and Preoperative Risk Factors*

Variable	Almassi et al. (6)	Aranki et al. (2)	Creswell et al. (11)	Fuller et al. (19)	Gavaghan et al. (14)	Hashimoto et al. (9)
Patients, <i>n</i>	3855	570	3983	1666	1247	800
Patients with AF, <i>n</i>	1142	189	1378	473	297	186
Incidence of AF, %	30	33	35	28	24	23
Definition of AF	NS	AF requiring medication or pacing	AF detected by telemetry and requiring treatment	Any duration of AF detected by continuous telemetry	NS	Any new onset of AF
Patients with AF/patients with surgery, <i>n/n</i> (%)						
CABG alone	863/3126 (28)	189/570 (33)	905/2833 (32)	473/1666 (28)	225/898 (25)	186/800 (23)
CABG and aortic valve replacement	83/228 (36)		95/158 (60)			
CABG and mitral valve replacement	21/35 (60)		65/103 (63)			
Aortic valve replacement	76/231 (33)		83/170 (49)		26/116 (22)	
Mitral valve replacement	20/41 (49)		43/97 (44)		8/52 (15)	
Transplantation			15/136 (11)			
Other†	79/194 (41)		172/486 (35)		8/181 (4)	
Multivariate predictors of AF: odds ratios (95% CI)						
Age	1.6 (1.5–1.8)‡ <i>P</i> < 0.001	2.0 (1.3–3.0)§ <i>P</i> < 0.001	NS <i>P</i> < 0.001	NS <i>P</i> = 0.001		2.4¶** <i>P</i> < 0.001
Hypertension	1.2 (1.0–1.4) <i>P</i> < 0.05	1.6 (1.0–2.3) <i>P</i> < 0.05	**	**		**
Male sex		1.7 (1.1–2.7) <i>P</i> = 0.01	**	NS <i>P</i> < 0.05		**
Previous AF						2.5¶ <i>P</i> = 0.0001
Previous congestive heart failure						**

* AF = atrial fibrillation; CABG = coronary artery bypass grafting; NS = not stated.

† Other types of surgery included atrial septal defect repair, multiple valve repair, cardiac tumor resection, and aneurysm-ectomy.

‡ Per 10-year increase in age.

§ For patients 70 to 80 years of age.

|| Not evaluated as a multivariate predictor in the given study.

¶ 95% CIs were not reported.

** For patients older than 65 years of age.

** Per 5-year increase in age.

** Not a significant multivariate predictor.

ing atrial fibrillation after cardiac surgery are incompletely understood; however, episodes are probably initiated by triggers, such as atrial premature contractions, in patients with a susceptible underlying atrial substrate. Occasionally, atrial fibrillation may be caused by a rapidly firing atrial focus (27), although the importance of this mechanism among patients with postoperative atrial fibrillation has not yet been clarified (28).

Reentry and atrial fibrillation are facilitated when adjacent atrial regions have widely disparate refractory periods (28–30). Slowed atrial conduction also facilitates reentry, and this probably explains the observed relation between a prolonged P-wave duration, as measured from a signal-averaged electrocardiogram, and the increased risk for atrial fibrillation following cardiac sur-

gery (25). Atrial incisions, atrial ischemia, and associated cardiac disease contribute not only to abnormal atrial conduction and refractoriness but also to the increased frequency of triggering events. Atrial premature beats occur more often in the minutes (12) and hours (16) before onset of atrial fibrillation. Some (12) but not all (16) studies also provide evidence for increased sympathetic activation preceding atrial fibrillation.

The role of atrial ischemia in the development of the underlying substrate and the triggering of atrial fibrillation after cardiac bypass operations has been studied. Although cardioplegia administered through the coronary circulation effectively arrests ventricular mechanical and electrical activity, the atrial septum remains significantly warmer than the ventricle (31) and usually

Table 1—Continued

Leitch et al. (10)	Mathew et al. (3)	Total
5807	2265	20 193
999	617	5281
17	27	26
AF detected by telemetry or symptoms and confirmed by electrocardiography	AF detected on two consecutive routine electrocardiograms or review of medical records	
999/5807 (17)	526/2048 (26)	4366/17 748 (25)
		178/386 (46)
		86/138 (62)
		185/517 (36)
		56/159 (35)
		15/136 (11)
		259/861 (30)
1.7 (1.6–1.9)†	1.2 (1.2–1.3)††	
P < 0.001	P < 0.01	
††	††	
	1.4 (1.1–1.8)	
	P < 0.01	
	2.3 (1.7–3.0)	
	P < 0.01	
	1.3 (1.0–1.6)	
	P < 0.05	

retains electrical activity (32)—a sign of inadequate myocardial protection (33). Persistence of atrial electrical activity during bypass is associated with postoperative atrial arrhythmias (32, 34). Poorer myocardial preservation, as measured by elevation of creatine kinase-MB, also correlates with postoperative atrial fibrillation (35).

Not all evidence indicates that atrial ischemia plays a significant role in atrial fibrillation after cardiac surgery. The degree of atrial hypothermia has no effect on the atrial effective refractory period or on inducibility of atrial fibrillation in a canine model (29). The lower incidence of atrial fibrillation observed in pediatric cardiac surgery and in cardiac transplantation, situations in which atrial ischemia often occurs, suggests that atrial ischemia probably does not play the sole etiologic role.

Complications of Atrial Fibrillation after Cardiac Surgery

Many complications of coronary artery bypass surgery occur more often in patients who develop postoperative atrial fibrillation than in patients who do not (2, 3, 6, 10, 11, 17, 36–39). Because ill patients more com-

monly develop atrial fibrillation, it is not surprising that atrial fibrillation is more frequent in patients returning to the operating room for complications (2), patients who are readmitted to the intensive care unit in the postoperative period (6), and patients requiring prolonged ventilation or reintubation (2, 6). Atrial fibrillation also occurs more frequently in postoperative patients with pneumonia (2), perioperative myocardial infarction (6), congestive heart failure (3), cardiac arrest (2, 11), ventricular arrhythmias (2, 11), or renal failure (2, 10). Overall, patients who develop postoperative atrial fibrillation have significantly increased 30-day and 6-month mortality rates compared with patients who do not experience postoperative atrial fibrillation (6).

Although atrial fibrillation is often a marker for severity of illness and not necessarily a cause of increased morbidity, some complications may be more directly a consequence of the arrhythmia. Patients with atrial fibrillation after cardiac surgery are more likely than patients who do not develop postoperative atrial fibrillation to have a cerebrovascular accident during hospitalization (2, 6, 11, 36, 37). Atrial fibrillation may cause hypotension or pulmonary edema (17), and stroke and cardiac index improve significantly in some patients after sinus rhythm is restored (38, 39). Patients with atrial fibrillation are also more likely to need a permanent pacemaker postoperatively (11). Even after adjustment for level of illness, patients with atrial fibrillation have longer stays in the intensive care unit (3, 6, 11) and in the hospital overall (2, 3). It has been estimated that hospital charges are \$10 000 to \$11 000 more per patient with atrial fibrillation (2).

PREDICTORS OF ATRIAL FIBRILLATION AFTER CARDIAC SURGERY

Several factors are associated with the development of atrial fibrillation after cardiac surgery. These factors can be classified as preoperative, intraoperative, or postoperative.

Preoperative Factors

Table 1 shows the preoperative factors associated with an increased incidence of atrial fibrillation after cardiac surgery. Older age has consistently predicted a higher incidence of postoperative atrial fibrillation (2–7, 9–12, 19, 25); incidence is increased by at least 50% per

decade of older age (3, 6, 7, 10). Older age also predicts atrial fibrillation in the general population (40), possibly because of increased atrial fibrosis and dilation (41).

Large, well-conducted observational studies have yielded conflicting results on the independent predictive value of other preoperative factors (Table 1). Hypertension, a predictor of atrial fibrillation in the general population (40), appears to predict atrial fibrillation after cardiac surgery (2, 6), and this may be related to associated fibrosis and dispersion of atrial refractoriness. Men appear more likely than women to develop post-CABG atrial fibrillation (2, 6, 7, 19, 25); sex differences in ion-channel expression and hormonal effects on autonomic tone may explain this disparity. Previous atrial fibrillation (3, 9) and previous congestive heart failure (3) are also predictors of postoperative atrial arrhythmias. An elevation in left ventricular end-diastolic pressure before surgery has been shown in some (9) but not all (3) studies to predict postoperative atrial fibrillation.

Intraoperative Factors

Some (3, 11, 15) but not all (2, 9, 19) studies show that aortic cross-clamp time correlates with postoperative atrial fibrillation, possibly because of the relation between cross-clamp time and atrial ischemia. Location of venous cannulation has also been related to the incidence of postoperative atrial fibrillation. Pulmonary vein venting has been associated with increased risk for postoperative atrial fibrillation (3, 6), while bicaval cannulation (which avoids incisions in the atria) has been associated with atrial fibrillation in some studies (3) but not others (42).

Postoperative Factors

Respiratory compromise, including pneumonia (2), chronic obstructive lung disease (6, 10, 11), and prolonged ventilation (2) are associated with atrial fibrillation after cardiac surgery. The need for postoperative atrial pacing is also associated with atrial fibrillation (3), and this probably reflects underlying sinus-node dysfunction and use of rate-controlling medications.

PROPHYLAXIS AND PREVENTION

Because of the high incidence of atrial fibrillation after cardiac surgery and the associated morbidity, mortality, and cost, much attention has focused on prevention of atrial fibrillation (Table 2).

Numerous randomized, controlled trials have demonstrated the benefit of prophylactic use of β -adrenergic blockade in patients undergoing cardiac surgery (5, 7, 18–20, 48, 60–65). Preoperative initiation of β -blockade appears more effective than postoperative initiation (5). A meta-analysis (5) was performed on 24 randomized, controlled trials involving patients who had an ejection fraction of 0.30 or greater and did not have bronchospasm, type 1 diabetes mellitus, atrioventricular block, or sick sinus syndrome. The meta-analysis demonstrated that therapy with a β -adrenergic blocker decreased the incidence of post-CABG atrial fibrillation by 77% (5). The benefit of preoperative therapy with a β -adrenergic blocker probably relates to a blunting of the effects of high sympathetic tone that occurs after cardiac surgery, as evidenced by elevated levels of right atrial norepinephrine (12). Digoxin (5, 18, 20, 23, 60) and verapamil (5, 21, 22) administered prophylactically do not reduce the incidence of postoperative arrhythmias, although use of these agents does decrease heart rates in cases of subsequent atrial fibrillation (5). In studies involving more than 200 patients total, intravenous diltiazem reduced the incidence of postoperative atrial fibrillation by more than two thirds compared with intravenous nitroglycerin (43, 44). No placebo-controlled trials have evaluated diltiazem for prevention of post-CABG atrial fibrillation.

Numerous well-conducted trials have investigated the efficacy of antiarrhythmic drug prophylaxis to prevent atrial fibrillation after cardiac surgery (Table 2). In selected patients, amiodarone appears to offer the greatest promise. Prophylactic amiodarone has been shown to decrease the incidence of post-CABG atrial fibrillation in several (55, 57, 58) but not all (56, 59) studies. Oral amiodarone at a dosage of 600 mg per day for 7 days before surgery and 200 mg per day postoperatively until hospital discharge decreases the incidence of post-CABG atrial fibrillation by 45% (57). Likewise, intravenous amiodarone administered postoperatively appears to decrease the incidence of postoperative atrial fibrillation by 26% to 76% (55, 56, 58, 66). In general, these trials excluded patients with a low resting heart rate (<50 beats/min), second- or third-degree atrioventricular block, or class III or IV congestive heart failure (New York Heart Association classification). Because fewer than half of the patients in these studies were treated with concomitant β -blockers, and because no study has

Table 2. Summary of Trials Investigating Prophylactic Drug Use for the Prevention of Atrial Arrhythmias in Patients Undergoing Cardiac Surgery

Drug (Reference)	Dosage	Control	Randomized Trial	Double-Blind	Patients, n	Odds Ratio (95% CI)
β -adrenergic antagonist (5)	Various*	Placebo	Yes	*	1549	0.28 (0.21–0.36) \checkmark
Digoxin (5)	Various*	Placebo	Yes	*	507	0.97 (0.62–1.49)
Verapamil (5)	Various*	Placebo	Yes	*	432	0.91 (0.57–1.46)
Diltiazem (43)†	0.1 mg/kg per h intravenously	Intravenous nitroglycerin	Yes	No	91	0.23 (0.06–0.89) \times
Diltiazem (44)†	0.1 mg/kg per h intravenously	Intravenous nitroglycerin	Yes	No	120	0.20 (0.04–0.99) \checkmark
Class I agents						
Procainamide (45)	12 mg/kg intravenously, then 2 mg/min intravenously	Placebo	Yes	Yes	100	0.37 (0.09–1.45)
Procainamide (46)	500–1000 mg orally every 6 h	Placebo	Yes	Yes	46	0.57 (0.24–1.34)
Propafenone (47)	300 mg orally twice daily	Atenolol	Yes	Yes	207	0.83 (0.35–1.94)
Class III agents						
Sotalol (48)	0.3 mg/kg intravenously, then 80 mg orally three times daily	No sotalol	Yes	No	91	0.04 (0.01–0.35) \checkmark
Sotalol (48)	0.3 mg/kg intravenously, then 80 mg orally three times daily	Metoprolol	Yes	No	80	0.14 (0.02–1.20)
Sotalol (49)	40–80 mg orally three times daily	Propranolol	Yes	No	429	0.77 (0.43–1.37)
Sotalol (50)	160 mg orally twice daily	Half-dose β -blocker	Yes	No	101	0.27 (0.09–0.80) \checkmark
Sotalol (51)	40 mg orally four times daily	Placebo	Yes	Yes	300	0.39 (0.23–0.68) \checkmark
Sotalol (52)‡	80 mg orally twice daily	Placebo	Yes	Yes	255	0.42 (0.24–0.71) \times
Sotalol (53)‡	80 mg orally twice daily	Placebo	Yes	Yes	214	0.45 (0.25–0.80) \times
Sotalol (54)	80–120 mg orally twice daily	Placebo	Yes	Yes	85	0.24 (0.08–0.72) \times
Amiodarone (55)	300 mg every 2 h, then 0.9–1.2 g/d for 4 d starting 2 h after surgery	Placebo	Yes	No	77	0.20 (0.04–1.00)
Amiodarone (56)	15 mg/kg intravenously, then 200 mg orally three times daily for 5 d starting at surgery	Placebo	Yes	Yes	120	0.80 (0.31–2.02)
Amiodarone (57)	200 mg orally three times daily for 7 d before surgery, then 200 mg/d orally until discharge	Placebo	Yes	Yes	124	0.29 (0.14–0.62) \checkmark
Amiodarone (58)	1 g/d intravenously for 2 d starting within 3 h after surgery	Placebo	Yes	Yes	300	0.61 (0.39–0.98) \checkmark
Amiodarone (59)	2-g divided doses orally before surgery, then 400 mg/d orally every day for 7 d after surgery	Placebo	Yes	Yes	143	0.67 (0.32–1.39)

* Meta-analysis that included blinded and unblinded trials.

† Patient populations may overlap.

‡ Patient populations may overlap.

compared amiodarone and β -blockade combined therapy with β -blockade alone, it is not certain that amiodarone offers any additional benefit in atrial fibrillation prophylaxis beyond those of β -blockers alone. Amiodarone generally can be administered safely, especially over the short term (use for a few days to several weeks). All patients, however, should be carefully monitored for evidence of organ toxicity, most commonly liver, pulmonary, thyroid, ocular, or neurologic in nature (67).

Sotalol, another class III antiarrhythmic agent with

potassium-channel and β -adrenergic blocking effects, has been shown to decrease the incidence of postoperative atrial fibrillation compared with placebo (51–54) or half-dose β -blockade (50); however, data on sotalol compared with full-dose β -blockade have been less conclusive (48, 49).

Few data are available to evaluate the prophylactic efficacy of the type IA antiarrhythmic drugs. No randomized, controlled trials of quinidine or disopyramide have been performed. Procainamide, another type IA

Table 3. Summary of Prophylactic Pacing Trials for Prevention of Atrial Fibrillation after Cardiac Surgery*

Study (Reference)	Patients <i>n</i>	Patients with Postoperative AF, according to Atrial Pacing Site				P Value†	Description of Pacing
		No Pacing	Right	Left	Biatrial		
Blominaert et al. (72)	96	27	10	—	—	<0.05	Atrial overdrive pacing for 24 h
Chung et al. (75)	100	29	26	—	—	‡	AAI pacing of 90–100 beats/min for 96 h
Gerstenfeld et al. (76)	61	33	29	—	37	‡	AAI pacing of 100 beats/min for 96 h
Greenberg et al. (73)	154	38	8	20	26	<0.005	AAI pacing of 100–110 beats/min for 72 h

* AF = atrial fibrillation; AAI = atrial inhibited.
 † P value for the comparison of no pacing versus any pacing.
 ‡ Not significant.

agent, has not been shown to reduce the number of patients developing post-CABG atrial arrhythmias when administered intravenously or orally in small numbers of patients (45, 46). Likewise, prophylactic administration of the type IC drug propafenone does not reduce the incidence of postoperative atrial fibrillation compared with β -blockers (47). Prophylactic flecainide, another type IC medication, has not been evaluated in the post-CABG setting.

Decreased postoperative magnesium levels are associated with atrial fibrillation (12), and prophylactic administration of magnesium reduces the incidence of atrial arrhythmias after cardiac surgery (68, 69). Magnesium is a cofactor for the myocardial cell membrane enzyme Na-K adenosine triphosphatase, which regulates transmembrane sodium and potassium gradients. Magnesium deficiency may predispose to arrhythmias by altering membrane potential and repolarization via its effect on this enzyme (68). Magnesium repletion is inexpensive and safe and should be considered in all patients undergoing cardiac surgery.

Chronic single-site and dual-site atrial pacing have been reported to prolong arrhythmia-free intervals in patients with drug-refractory atrial fibrillation unrelated to cardiac surgery (70, 71). In a randomized trial of 96 patients, prophylactic use of continuous atrial overdrive pacing decreased the incidence of postoperative atrial fibrillation after CABG by 63%; the continuous atrial overdrive pacing was done through temporary epicardial wires by using an algorithm that paces the atria just above the patient's intrinsic rate and that responds to premature atrial beats (72). Pacing may reduce the incidence of atrial fibrillation by reducing the number of triggering events (premature atrial beats) or by reducing

the dispersion of atrial refractoriness (73, 74). Right, left, and biatrial pacing each decrease the incidence of atrial fibrillation after cardiac surgery compared with no atrial pacing, although atrial fibrillation appears to occur least frequently in patients who undergo pacing from the right atrium (73). Of note, not all studies have shown a decreased incidence of atrial fibrillation in patients who have undergone pacing (Table 3) (75, 76), and epicardial pacing may result in proarrhythmia or diaphragmatic stimulation (75, 77). Overall, postoperative atrial pacing decreases the duration of hospital stay by more than 20% (73).

In summary, all patients without contraindications should receive β -adrenergic blockers before and after cardiac surgery. Prophylactic preoperative and postoperative amiodarone therapy (started up to 7 days before surgery) and prophylactic postoperative atrial pacing are reasonable options in patients at high risk for postoperative atrial fibrillation, including patients with previous atrial fibrillation who are experiencing sinus rhythm preoperatively, patients undergoing mitral valve surgery, and older patients. These prophylactic therapies are particularly attractive options if management of postoperative atrial fibrillation with anticoagulation alone or rate control alone is expected to be difficult.

TREATMENT

Spontaneous conversion of atrial fibrillation after cardiac surgery is common; 15% to 30% of patients convert within 2 hours (14, 78) and 25% to 80% of patients convert within 24 hours when either digoxin alone or no antiarrhythmic therapy is administered (79, 80). Two management strategies are available to treat

patients with persistent or recurrent atrial fibrillation: rate control and rhythm control (Figure). For patients who are hemodynamically unstable or highly symptomatic or who have a contraindication to anticoagulation, rhythm control is preferred. For patients in whom restoration of sinus rhythm is less important, rate control is preferred.

Rate Control

Because of the high sympathetic tone after surgery, β -adrenergic blockers are considered first-line therapy for patients with rapid ventricular response to atrial fibrillation (5). When β -blockade alone inadequately controls heart rate, calcium-channel blockers (verapamil or diltiazem) may be administered orally or intravenously. Digoxin may help slow the ventricular response at rest, but this agent seldom adequately controls the heart rate response when sympathetic tone is high. Amiodarone may provide adequate rate control in patients intolerant of β -blockers and calcium-channel blockers because of hypotension, although rapid infusion of intravenous amiodarone may also cause hypotension (80).

Antiarrhythmic Drug Treatment

If persistent or recurrent atrial fibrillation warrants antiarrhythmic therapy, care should be taken to reduce the risk for drug-induced proarrhythmia by carefully monitoring electrolyte repletion. Patients with previous myocardial infarction, reduced ejection fraction, or older age are at particularly high risk for developing drug-induced proarrhythmia (81, 82). The risk is highest in the first 48 hours of drug therapy; therefore, patients should be monitored during this time period (81). Amiodarone may be a possible exception and has been started safely in the outpatient setting in patients at low risk for bradyarrhythmias (57).

Type IA and type IC agents have shown efficacy for conversion of post-CABG atrial fibrillation. Intravenous administration generally results in conversion to sinus rhythm in 40% to 75% of patients within 1 hour (39, 83–85) and in 50% to 90% within 12 hours (14, 71, 79, 86, 87) (Table 4). Efficacy of oral administration of these drugs after cardiac surgery has not been well studied. A small trial of oral quinidine demonstrated a conversion rate of almost two thirds within 8 hours (88). Similarly, oral propafenone converted 65% of patients

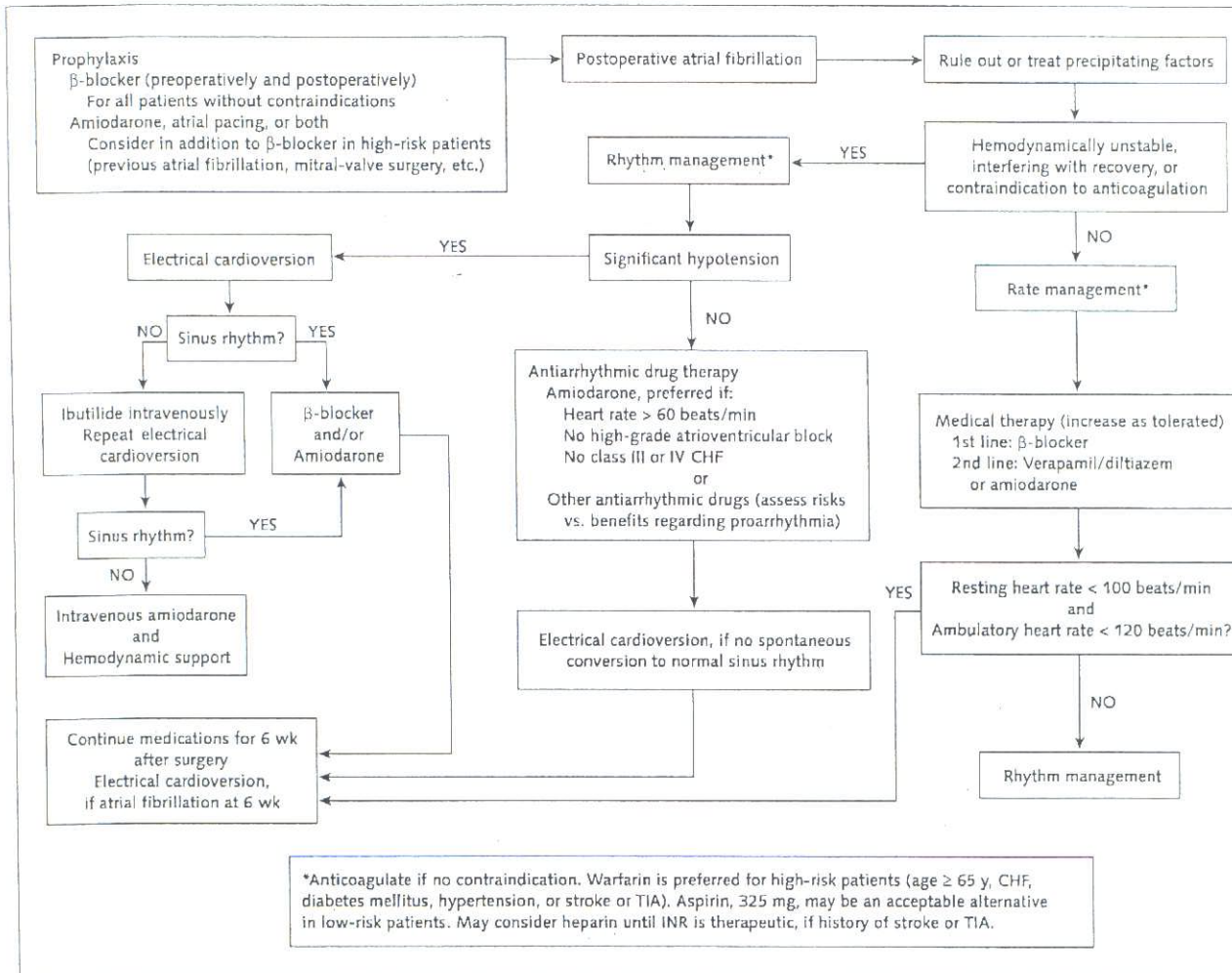
with non-CABG atrial fibrillation within 8 hours (91), but oral propafenone has not been specifically studied in patients after cardiac surgery. Because of the demonstrated increased mortality in post-myocardial infarction patients receiving type IC agents for ventricular premature beats, these medications should be avoided in post-CABG patients (92, 93).

Intravenous class III antiarrhythmic drugs (sotalol, amiodarone, ibutilide, and dofetilide) appear to have efficacy similar to that of class IA and IC agents for the acute conversion of post-CABG atrial fibrillation (Table 4) (78, 80, 86, 88–90). Intravenous amiodarone leads to conversion to sinus rhythm within 12 to 24 hours in 40% to 90% of patients with atrial fibrillation after cardiac surgery (80, 88, 89). Although this rate is similar to that noted with other antiarrhythmic agents, amiodarone therapy provides effective rate control, has a lower risk for proarrhythmia, and is easily converted to oral therapy. For these reasons, amiodarone is preferred for patients who will require ongoing antiarrhythmic therapy after hospital discharge.

Ibutilide, a newer class III agent, was recently approved for acute conversion of atrial fibrillation. Up to 44% of patients receiving intravenous ibutilide (1-mg infusion over 10 minutes, then repeated 10 minutes after completion of the infusion if atrial fibrillation persists), compared with 15% of patients receiving placebo, for atrial fibrillation after cardiac surgery have converted to sinus rhythm (78). Patients with atrial flutter had a 78% conversion rate. Ibutilide may also be a useful adjunct when electrical cardioversion fails to restore sinus rhythm. Administration of ibutilide before repeated electrical cardioversion is attempted results in higher success rate of cardioversion and lower energy requirements (94). Ibutilide infusion for chemical cardioversion or for electrical cardioversion pretreatment has been associated with a 2% to 3% risk for the polymorphic ventricular arrhythmia, torsade de pointes (78, 94). For patients who are closely monitored and who have immediate access to external defibrillation, ibutilide is a reasonable choice for the acute conversion of atrial fibrillation (if electrolytes and QT interval are normal at baseline). Oral preparations of ibutilide are not currently available.

Dofetilide, a class III drug similar to ibutilide, converts approximately 40% of patients to sinus rhythm when administered intravenously (the intravenous formula is not available in the United States) (90). When

Figure. Algorithm for the prevention and management of atrial fibrillation after cardiac surgery.



All patients without contraindication should receive prophylaxis to prevent atrial fibrillation. If atrial fibrillation does occur after cardiac surgery, a strategy of rhythm management or rate management should be chosen. For patients who are hemodynamically unstable or highly symptomatic or who have a contraindication to anticoagulation, rhythm management is preferred. Unstable patients should undergo urgent electrical cardioversion to sinus rhythm. For patients who less urgently require sinus rhythm restoration, antiarrhythmic drug therapy may be used. Oral loading of amiodarone (400 mg three times daily for 5 days, followed by 200 to 400 mg/d) is preferred for patients without congestive heart failure (CHF), heart block, or bradycardia. Other antiarrhythmic agents (for example, procainamide or sotalol) may be considered in patients with persistent or recurrent atrial fibrillation despite amiodarone therapy or in patients with contraindication to amiodarone therapy. In general, these other agents are advised only when restoration of sinus rhythm is of paramount importance, as they carry a greater risk for development of proarrhythmia.

For patients in whom sinus rhythm restoration is less important, rate management is the preferred strategy. Verapamil, diltiazem, or amiodarone is available for patients with a rapid heart rate despite β-blocker therapy. Digoxin seldom provides adequate rate control and has a narrow therapeutic window. For patients with recurrent rapid atrial fibrillation despite attempts at rate control, consideration should be given to restoring sinus rhythm by using antiarrhythmic medication or electrical cardioversion. Whichever strategy is used, patients should be maintained on their atrial fibrillation medications for 6 weeks after surgery, at which point discontinuation can be considered if sinus rhythm persists.

All patients without contraindication should receive anticoagulation if atrial fibrillation persists beyond 24 to 48 hours. Warfarin is preferred, although aspirin, 325 mg, may be an acceptable alternative in low-risk patients. In patients with atrial fibrillation after coronary artery bypass graft surgery who are at particularly high risk for stroke (for example, patients with a previous stroke or transient ischemic attack [TIA]), heparin therapy may be considered for stroke prevention but must be weighed carefully against the risk for postoperative bleeding.

administered orally, dofetilide reduces the incidence of atrial fibrillation among patients with congestive heart failure (95), but its efficacy has not been studied specif-

ically in post-CABG patients. Patients treated with dofetilide are at risk for torsade de pointes and require dose calculation based on creatinine clearance and re-

quire in-hospital telemetry monitoring for at least 72 hours after treatment initiation (95).

Overall, although many antiarrhythmic drug options are available to treat patients with atrial fibrillation in whom restoration of sinus rhythm is desired, the combination of reasonable efficacy, ease of administration, and low risk for proarrhythmia often makes amiodarone the agent of choice for patients requiring ongoing antiarrhythmic drug treatment, particularly if left ventricular ejection fraction is depressed (Figure).

Anticoagulation

Patients with atrial fibrillation for more than 48 hours should be strongly considered for anticoagulation. Specific data are lacking to guide the management of anticoagulation in patients with atrial fibrillation after cardiac surgery. Aspirin, 325 mg/d, decreases the risk for thromboembolic events compared with placebo in non-surgical patients (96). The potential benefits of anticoagulation with warfarin or heparin must be weighed carefully against the perceived risk for postoperative bleeding. Trials assessing the effect of anticoagulants on graft patency have demonstrated that warfarin can be administered in the immediate post-CABG period with only a minimal resultant risk for bleeding (97, 98), al-

though there appears to be a higher rate of large pericardial effusions and cardiac tamponade in patients receiving warfarin compared with those receiving aspirin or placebo (98, 99). Because the utility of heparin to prevent thrombus formation in post-CABG patients with atrial fibrillation is unknown and because the risk for postoperative bleeding is likely to be increased by using heparin therapy, routine use of heparin is unadvisable. Heparin infusion while awaiting a therapeutic international normalized ratio may be considered in very high-risk patients, such as those with atrial fibrillation and a history of stroke or transient ischemic attack.

In the absence of more specific data on patients who have post-CABG atrial fibrillation, it is reasonable to follow the American Heart Association anticoagulation guidelines for patients with atrial fibrillation (100). Warfarin (with a target INR of 2 to 3) should be administered to patients with 48 hours or more of atrial fibrillation who are at increased risk for stroke—including patients with hypertension, diabetes mellitus, congestive heart failure, previous stroke, or previous transient ischemic attack or if they are older than 65 years of age—unless a specific contraindication exists. Aspirin may be an acceptable alternative in lower-risk patients.

Transesophageal echocardiography can identify pa-

Table 4. Summary of Drug Therapy for Acute Conversion of Atrial Arrhythmias after Cardiac Surgery*

Drug (Reference)	Dosage and Route	Double-Blind	Patients Treated	Time Course	Conversion Rate (95% CI)
			n	h	%
Class IA agents					
Disopyramide (79)	IV 2 mg/kg, then IV 0.4 mg/kg per h	No	25	12	68 (50–86)
Disopyramide (86)	IV 2 mg/kg, then IV 0.4 mg/kg per h	No	20	12	85 (69–100) ✗
Disopyramide (87)	IV 2 mg/kg, then IV 0.4 mg/kg per h	No	27	12	89 (77–100) ✗
Disopyramide (14)	IV 2 mg/kg, then IV 0.4 mg/kg per h or 600 mg orally every day	No	156	12	48 (40–56)
Quinidine (88)	400 mg orally; repeat once after 4 h	No	39	8	64 (49–79)
Procainamide (83)	IV 20 mg/kg	Yes	33	≤1	61 (44–78)
Class IC agents					
Propafenone (83)	IV 2 mg/kg over 10 min	Yes	29	≤1	76 (60–92) ✗
Propafenone (39)	IV 2 mg/kg over 10 min	No	50	≤1	70 (57–83) ✗
Propafenone (84)	IV 2 mg/kg over 10 min	Yes	14	≤1	43 (17–69)
Flecainide (85)	IV 1 mg/kg over 10 min, then IV 1.5 mg/kg over 1 h, then IV 0.25 mg/kg per h for 23 h	No	15	1	67 (43–91)
Flecainide (87)	IV 2 mg/kg over 20 min, then IV 0.2 mg/kg per h for 12 h	No	29	12	86 (73–99) ✗
Class III agents					
Sotalol (86)	IV 1 mg/kg, then IV 0.2 mg/kg over 12 h	No	20	12	85 (69–100) ✗
Amiodarone (88)	IV 5 mg/kg over 20 min	No	41	8	41 (26–56)
Amiodarone (89)	IV 2.5–5 mg/kg over 2–4 min, then IV 600–1200 mg per 24 h	No	32	12	56 (39–73)
Amiodarone (80)	IV 5 mg/kg over 30 min, then IV 25 mg/h	No	15	24	93 (80–100) ✗
Ibutilide (78)	IV 1 mg over 10 min; may repeat once	Yes	70	1.5	57 (45–69)
Dofetilide (90)	IV 4–8 µg/kg over 15 min	Yes	65	3	40 (28–52)

* IV = intravenous.

Table 5. Summary of Key Points

1. Atrial fibrillation after cardiac surgery is common and occurs more frequently in older patients, patients with previous atrial fibrillation, and patients undergoing concomitant valve surgery.
2. Prophylactic β -blockade reduces the incidence of atrial fibrillation after coronary artery bypass graft surgery by more than 75% and should be administered to all patients without contraindication.
3. Other prophylactic regimens, including amiodarone and atrial pacing, should be used in patients at high risk for postoperative atrial fibrillation.
4. Restoration of sinus rhythm (rhythm management) should be pursued in patients with postoperative atrial fibrillation who are hemodynamically unstable or symptomatic or cannot receive anticoagulation. Rate management is appropriate for all other patients.

tients at low risk for cardioversion-related embolic events. Before elective cardioversion, transesophageal echocardiography should be done to exclude left atrial thrombus in patients with atrial fibrillation more than 48 hours who have not received therapeutic anticoagulation (101).

Prophylactic obliteration of the left atrial appendage at cardiac surgery has been suggested as a potential method to reduce postoperative stroke. Some patients, however, develop atrial thrombi in regions other than the appendage (102). Thus, anticoagulation in appropriate patients remains the most effective method for stroke reduction.

Electrical Cardioversion

External electrical cardioversion may be performed in patients in whom restoration of sinus rhythm is desired because of persistent symptoms or difficulty with rate control; however, most patients discharged with atrial fibrillation will spontaneously convert to sinus rhythm within 6 weeks of discharge (103). With antiarrhythmic therapy and electrical cardioversion, most patients with post-CABG atrial fibrillation can be discharged home in sinus rhythm (17). Fewer than 10% of patients with postoperative atrial fibrillation who are discharged in sinus rhythm will have recurrent atrial fibrillation in the 6 weeks after discharge (104). Continued administration of prophylactic calcium-channel blockers, quinidine, or amiodarone after discharge does not appear to influence the rate of recurrence (104).

SUMMARY OF TREATMENT RECOMMENDATIONS

A proposed algorithm for preventing and managing atrial fibrillation after cardiac surgery is shown in the Figure; Table 5 lists a summary of key points.

CONCLUSIONS

Atrial fibrillation often occurs after cardiac surgery and is associated not only with increased morbidity and mortality but also with increased costs and longer hospital stays. Prevention of atrial fibrillation with prophylactic administration of β -adrenergic blockers, antiarrhythmic medication, pacing, or a combination of therapies in appropriate patients can significantly decrease the incidence of atrial fibrillation, although optimal use of these strategies is still being defined. Treatment is directed to provide rate control; in symptomatic patients, restoring sinus rhythm with electrical cardioversion or antiarrhythmic medication may also be advisable. Anticoagulation is advisable for patients unable to maintain sinus rhythm. No matter the treatment, most patients will return to sinus rhythm within 6 weeks after surgery.

From Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts.

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Requests for Single Reprints: William H. Maisel, MD, MPH, Cardiovascular Division, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115; e-mail, wmaisel@partners.org.

Current Author Addresses: Drs. Maisel and Stevenson: Cardiovascular Division, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115.

Dr. Rawn: Division of Cardiac Surgery, Brigham and Women's Hospital, 75 Francis Street, Boston, MA 02115.

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