New-Onset Atrial Fibrillation After Cardiac Surgery: Pathophysiology, Prophylaxis, and Treatment

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AMONG ALL CARDIOVASCULAR complications, new-onset postoperative atrial fibrillation (POAF) is one of the most common complications, occurring in 30% to 50% of patients after cardiac surgery.[1] POAF occurs most frequently in the first 5 days after cardiac surgery, with a peak incidence on postoperative day 2.[2,3] POAF is associated with an increased risk of mortality and morbidity, predisposes patients to a higher risk of stroke, requires additional treatment, and increases postoperative costs.[4–6] Thus, POAF is a significant problem because its impact on hospital resources is substantial.[7] The pathophysiology of POAF after cardiac surgery is not known precisely, but the mechanisms are believed to be multifactorial and to include predisposing and perioperative factors and triggers.[8] Although a large body of research has been devoted to defining the precise mechanisms underlying POAF, those mechanisms remain far from being elucidated. In addition, the clinical significance of various drugs and techniques in the prevention of POAF also has not been determined.

The scope of this review article is to summarize current data regarding the pathophysiology, prevention, and treatment of new-onset POAF in cardiac patients.

PATHOPHYSIOLOGY

The underlying mechanisms of POAF are multifactorial and presently remain far from elucidated (Fig 1). It is believed that multiple mechanisms are responsible for POAF in individual patients. Many risk factors predispose patients to POAF (Table 1), leading to structural and electrophysiologic abnormalities and the development of a favorable environment for triggering and maintaining atrial fibrillation (AF).

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Myocardial atrial fibrosis is a common finding accompanying AF.[18] It has been shown that atrial fibrosis is associated with a history of stroke[19] and unfavorable results of catheter ablation.[20]

The areas that most frequently trigger activity are the left atrial myocardial sleeves that extend into the pulmonary veins. Because of this, pulmonary vein isolation has become essential during radiofrequency catheter ablation procedures.[21] Several histologic, anatomic, and electrophysiologic properties of pulmonary veins contribute to the high arrhythmogenic activity of this area. A unique myocardial fiber orientation, conduction abnormalities, short-acting potentials, and the refractoriness of myocytes are responsible for promoting re-entry.[22] Furthermore, the presence of melanocytes and interstitial cells additionally contribute to ectopic focal triggering activity.[23,24]

In addition to the pulmonary veins, other non-pulmonary foci responsible for triggering AF also have been described. Among them are the coronary sinus, ligament of Marshall, posterior wall of the left atrium and septum, vena cava, and appendages.

Three theories exist that explain AF maintenance: (1) independent re-entrant waves predisposed by the heterogeneity of areas with diverse conductivity and excitability; (2) one or more rapidly firing foci producing asynchronous action potentials in different sites of the atrium; and (3) the spiral wave re-entry (rotors) theory, which describes circulating waves in the absence of an anatomic obstacle.[25]

The important role of the autonomic nervous system in the development of AF has been investigated widely in recent years.[26] Sympathetic and parasympathetic stimulation can induce heterogenous and pronounced changes in cardiac electrophysiology through the key mechanisms of focal activity, including enhanced automaticity, early afterdepolarization, and delayed afterdepolarization-triggered activity.

Inter-individual susceptibility to POAF may be explained by personal variations in pre-existing structural substrates, as previously described, and by the surgical intervention itself, which introduces additional acute factors responsible for new-onset POAF.[27] Systemic and local inflammation due to pathophysiologic effects of cardiopulmonary bypass (CPB) and damage to the atrium by direct incision are unavoidable consequences of cardiothoracic procedures and contribute to the occurrence of POAF.[28] It is believed that surgical stress, as such, is a more significant trigger of POAF than is systemic inflammation.[27] Thus, attempts to reduce the incidence of

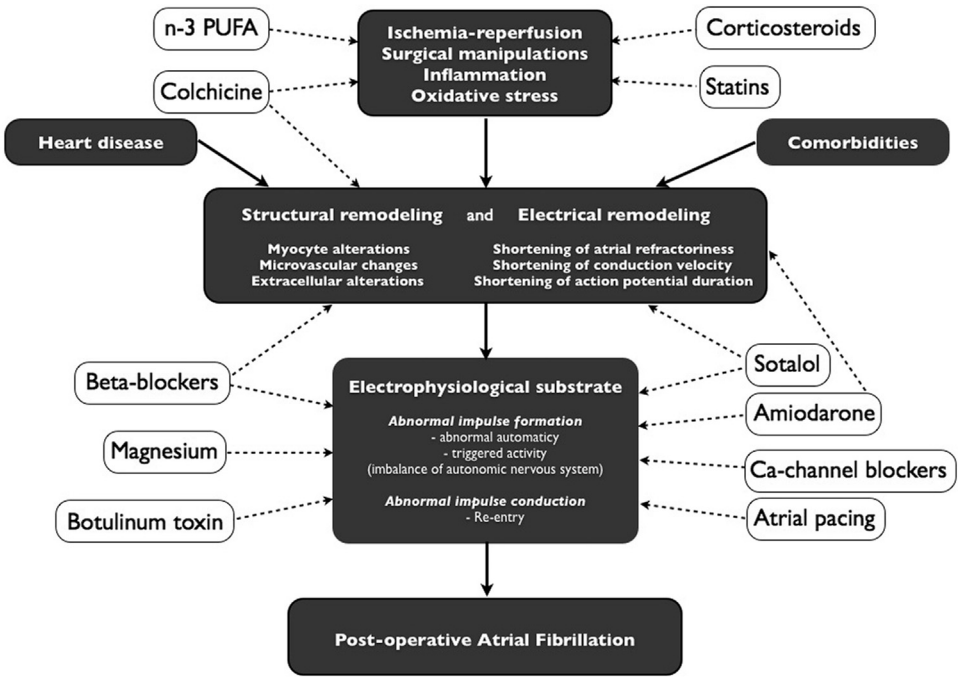

Fig 1. Factors contributing to the development of AF after cardiac surgery and sites of action for drugs for AF prophylaxis. The mechanisms underlying postoperative atrial fibrillation (POAF) are not precisely known. Cardiac disease per se and comorbidities cause significant alterations in myocardial metabolism. Coupled with numerous intraoperative factors (eg, ischemia/reperfusion injury, surgical manipulations, inflammatory response, oxidative stress), they promote structural and electrical remodeling of cardiomyocytes. The occurrence of abnormal impulse formation (eg, caused by an imbalance in the autonomic nervous system) and impulse conduction contribute to the development and maintenance of POAF.

Table 1. Risk Factors of New-Onset Postoperative Atrial Fibrillation [4,8–17]

Preoperative	Advanced age
	History of atrial fibrillation
	Hypertension
	Left atrial enlargement
	Chronic obstructive pulmonary disease
	Decreased left ventricular ejection fraction
	Higher EuroSCORE
	Heart failure
	Coronary artery disease
	Cardiomyopathies
	Valve disease
	Diabetes mellitus
	Obesity
	Smoking
	Alcohol use
	Hyperthyroidism
	Genetic predisposition
Intraoperative	Valve surgery
	On-pump surgery
	Venous cannulation
	Surgical pericardial and atrial injury
Postoperative	Hypervolemia
	Hypovolemia
	Increased afterload
	Hypotension
	Withdrawal of beta-blocker therapy
	Withdrawal of angiotensin-converting enzyme inhibitor therapy

POAF by implementing off-pump surgery, which elicits less systemic inflammation than do on-pump techniques,[29] were successful only among patients age 70 years and older.[30] Sympathetic activation is another acute factor playing an important role in the pathogenesis of new-onset POAF. Increased circulating catecholamine levels after cardiac surgery as a result of surgical stress and the administration of inotropic drugs also contribute to the development of POAF[31–34] due to enhanced myocardial excitability and automaticity.[35] Acute factors that promote AF after cardiac surgery also include oxidative stress,[36,37] variable perioperative pressure, and volume changes, including hypovolemia and hypervolemia.[8]

DIAGNOSIS

AF is a common supraventricular arrhythmia that is characterized by chaotic contraction of the atrium. An electrocardiogram (ECG) recording is necessary to diagnose AF. According to an expert consensus statement, an AF episode is defined as AF documented by ECG monitoring with a duration of at least 30 seconds, or, if less than 30 seconds, is present continuously throughout the ECG monitoring tracing.[21] Every patient who presents with AF for the first time is considered to have new-onset AF, irrespective of the duration of the arrhythmia. An AF episode also may be accompanied by hypotension, palpitation, dizziness, decreased urinary output, and fatigue, but it also sometimes may be asymptomatic.[38,39]

Cardiac patients are monitored closely after surgery while they are in intensive care. According to the joint guidelines of