shortening of the PR interval, and the initial part of the QRS complex is slurred because of premature ventricular depolarization in the myocardial tissue adjacent to the accessory pathway. In AVRT, conduction is anterograde over the AV node (orthodromic, narrow-complex AVRT) in 90% to 95% of cases; conduction is anterograde over the accessory pathway (antidromic, wide-complex AVRT) in the remaining cases.

Wolff-Parkinson-White (WPW) syndrome is defined by symptomatic AVRT with evidence of preexcitation on resting ECG. AF occurs in up to one-third of patients with WPW syndrome. Rapid conduction over an accessory pathway in AF can result in ventricular fibrillation (VF) and sudden cardiac death (SCD), although this occurs in less than 1% of cases of WPW syndrome.

Risk stratification for SCD can be performed with exercise testing, although more frequently, patients are referred for electrophysiology testing for both risk stratification and curative ablation. Catheter ablation is first-line therapy for patients with WPW syndrome. The success rate for ablation is high but is dictated by the location of the accessory pathway. Antiarrhythmic therapy is second-line therapy.

In asymptomatic patients with preexcitation on ECG, management is controversial. Invasive testing is generally not required unless the patient has a high-risk occupation, such as a commercial airline pilot.

Premature Atrial Contractions and Atrial Tachycardia

Premature atrial contractions (PACs) are early isolated beats that arise from the atria. They are exceedingly common, and their frequency increases with age. During ambulatory ECG monitoring, only 1% of persons have no PACs. High PAC burden is associated with increased risk for AF. Symptomatic PACs are typically treated with β-blockers or calcium channel blockers.

Atrial tachycardia can arise in the presence or absence of structural heart disease. β-Blocker or calcium channel blocker therapy is first-line treatment for symptomatic atrial tachycardia. Second-line treatment is catheter ablation or antiarrhythmic drug therapy. Ablation success rates are generally lower in patients with atrial tachycardia than in patients with other SVTs.

Multifocal atrial tachycardia is typified by three or more P-wave morphologies and a heart rate greater than 100/min (**Figure 23**). It is usually seen in patients with severe pulmonary disease.

KEY POINTS

- Vagal maneuvers may restore sinus rhythm in patients with supraventricular tachycardia.
- Patients with recurrent supraventricular tachycardia are treated with atrioventricular nodal blockers (β-blockers or calcium channel blockers) or catheter ablation.
- First-line therapy for patients with Wolff-Parkinson-White syndrome is catheter ablation; antiarrhythmic drugs are second-line therapy.

Atrial Fibrillation

AF is characterized by disorganized atrial activity with an irregularly irregular ventricular response on ECG (**Figure 24**). It is the most common sustained arrhythmia. Lifetime risk for AF is 25% in patients older than 40 years. Incidence is strongly associated with and increases with age, with 10% of persons older than 80 years affected. AF is associated with an increased risk for adverse cardiac events, including a fivefold increased

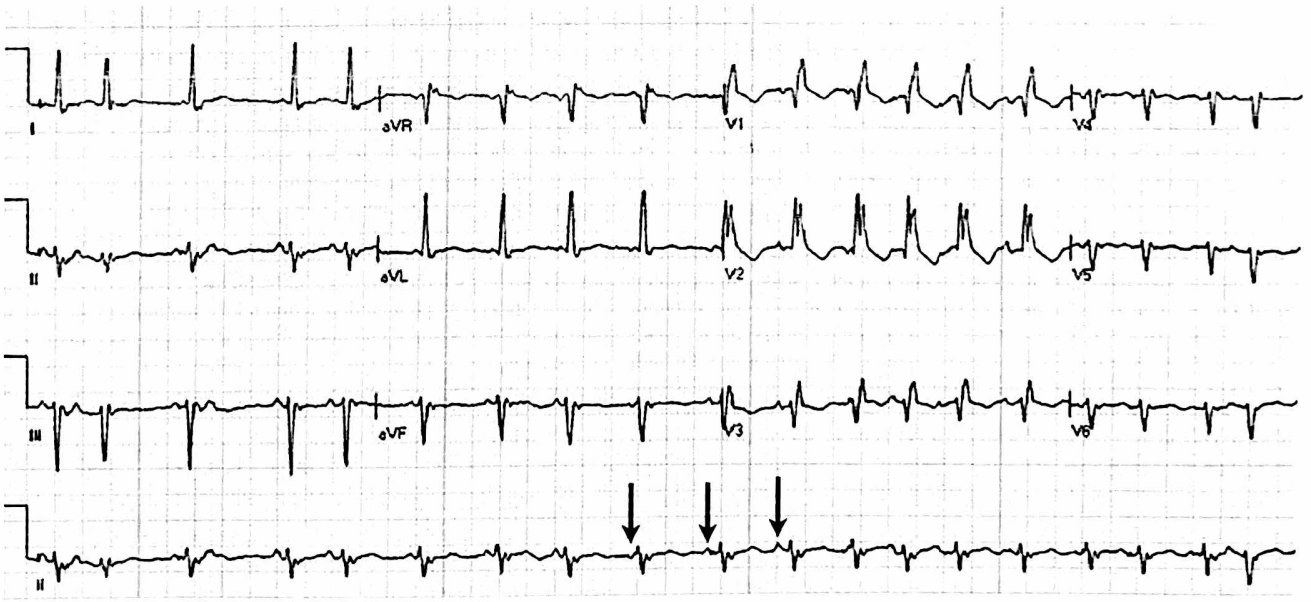

FIGURE 23. ECG showing multifocal atrial tachycardia typified by three or more P-wave morphologies (*arrows*).

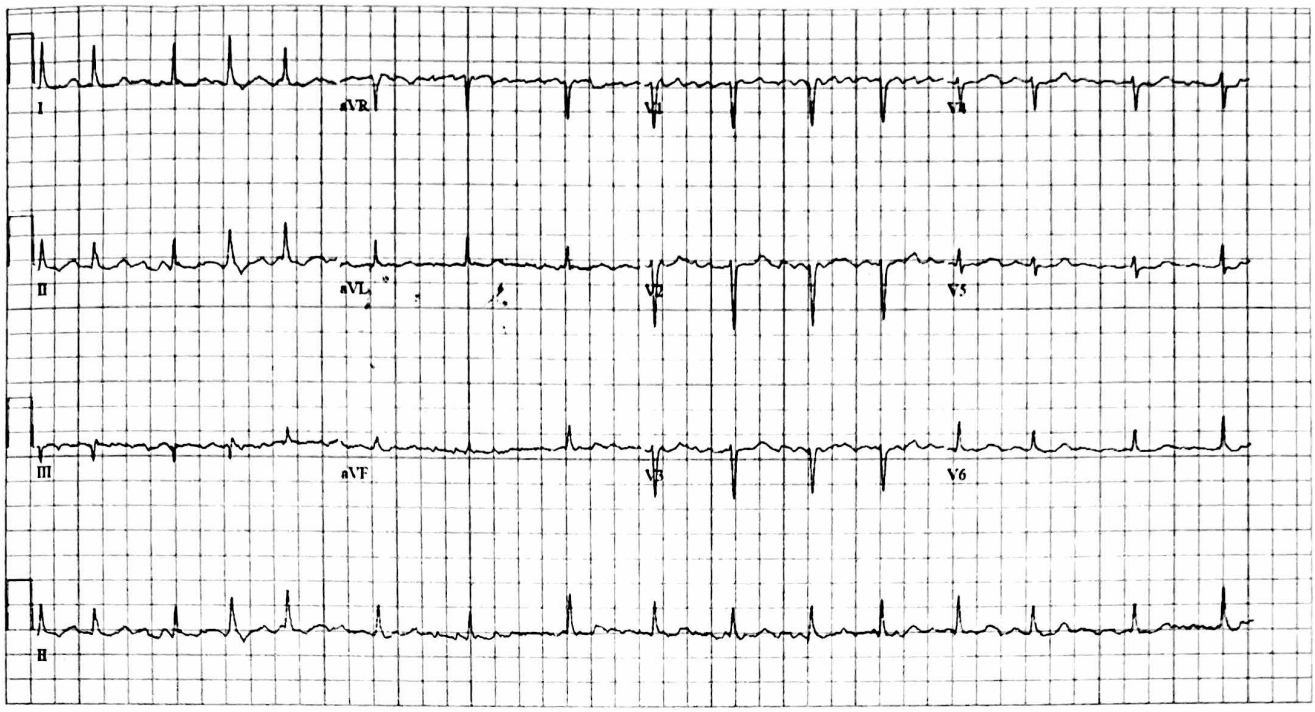

FIGURE 24. ECG demonstrating atrial fibrillation. No clear P waves are seen, and the ventricular response is irregular.

risk for stroke, as well as increased risk for heart failure and dementia. Among patients aged 55 years and older with an ischemic neurologic event (i.e., stroke or transient ischemic attack) of undetermined source, occult intermittent AF is thought to be present in up to 25% of cases, and 30-day ambulatory ECG monitoring is indicated for detection. If 30-day ambulatory monitoring is inconclusive, implantation of a cardiac monitor (loop recorder) is reasonable to optimize detection of silent AF.

AF is usually the result of long-standing risk factors, such as diabetes mellitus, smoking, moderate to heavy alcohol consumption, obesity, hypertension, coronary artery disease (CAD), heart failure, and obstructive sleep apnea. Behavioral risk factor modification, including increased activity, weight loss, smoking cessation, and abstinence from alcohol, is recommended. Bariatric surgery should be considered for appropriate candidates. Blood pressure and blood glucose control and obstructive sleep apnea management also reduce risk.

AF is less commonly caused by reversible or acute physiologic insults, including cardiac surgery, pulmonary embolism, critical illness, or hyperthyroidism. When there are no identified risk factors, a predisposing genetic background is often present.

Clinical Presentation

Patients with AF may be asymptomatic or experience palpitations, light-headedness, dizziness, dyspnea, exercise intolerance, chest pain, near-syncope, or, rarely, syncope. In some cases, AF can lead to hemodynamic compromise, especially in patients with advanced diastolic dysfunction or restrictive cardiomyopathy. Patients with AF less commonly present with tachycardia-induced cardiomyopathy, characterized by asymptomatic left ventricular (LV) dysfunction or overt heart failure.

AF is categorized according to its duration. Paroxysmal AF stops spontaneously within 7 days of onset, whereas persistent AF lasts for 7 days or more. Long-standing persistent AF is continuous, with a duration of more than 1 year. Permanent AF refers to cases in which the physician and patient have abandoned attempts to maintain sinus rhythm.

Acute Management

Urgent cardioversion (electrical or pharmacologic) is indicated in patients with AF and hypotension, acute myocardial ischemia, or decompensated heart failure. In patients with AF or atrial flutter of more than 48 hours' duration or unknown duration that requires immediate cardioversion, anticoagulation should be initiated as soon as possible and continued for at least 4 weeks unless contraindicated. The decision about long-term anticoagulation should be based on the thromboembolic risk profile and bleeding risk profile (see Long-Term Management).

In stable patients, the primary goals of therapy are to (1) prevent stroke, (2) control heart rate, (3) minimize or eliminate symptoms, and (4) modify underlying risk factors. Upon diagnosis, reversible causes must be ruled out. All patients should undergo thyroid function testing to evaluate for hyperthyroidism. Patients with risk factors for or symptoms suggestive of sleep apnea should undergo testing. Echocardiography is indicated to evaluate for potential valvular or other structural

heart disease. Echocardiography can also be used to assess left atrial size, which helps determine the severity of the underlying atrial myocardial dysfunction. Elective cardioversion can be pursued in patients with significant symptoms who are hemodynamically stable.

Acute Anticoagulation

In patients who are not undergoing cardioversion, acute intravenous anticoagulation is usually unnecessary; however, oral anticoagulation should be initiated if the patient has sufficient risk factors for stroke.

If cardioversion is planned, the duration of AF guides therapy. AF with a known duration of less than 48 hours confers a low risk for thrombus formation and subsequent stroke, and preprocedural anticoagulation can be considered in patients who are otherwise at low risk for stroke. Preprocedural anticoagulation is reasonable as soon as possible before cardioversion for men with a CHA_2DS_2-VASc score of 2 or greater and for women with a score of 3 or greater followed by long-term anticoagulant therapy. In patients in whom the duration of AF is unclear or in whom AF has lasted longer than 48 hours, anticoagulation therapy for 3 weeks is recommended before cardioversion. In patients who would benefit from cardioversion sooner, transesophageal echocardiography can be performed to exclude the presence of left atrial appendage thrombus and facilitate urgent cardioversion. Regardless of the duration or nature of AF, all patients who undergo cardioversion must receive anticoagulants for at least 4 weeks following the procedure because of an increased risk for thromboembolic events after sinus rhythm is restored.

Rate Control

Heart rate control is necessary in patients with rapid ventricular rates to improve cardiac function and alleviate symptoms. Acutely, the goal heart rate should be between 60/min and 110/min. Commonly used medications include AV nodal blockers, such as metoprolol or diltiazem. Intravenous or oral administration may be appropriate depending on symptoms. In patients with LV dysfunction, calcium channel blockers should be avoided. Digoxin can be used as adjunctive therapy to improve rate control, especially in patients with heart failure.

Long-Term Management

Anticoagulation

Arterial thromboembolic events are the most serious complication of AF and can occur with any form (paroxysmal, persistent, or permanent). In patients with nonvalvular AF (AF in the absence of a mechanical prosthetic valve or moderate/severe mitral stenosis), the absolute risk for stroke is approximately 4% per year; however, the presence of comorbidities (e.g., heart failure, hypertension, diabetes, or vascular disease) can increase the risk 15- to 20-fold. Hypertension is associated with an increased risk for both AF and stroke; therefore, blood pressure control is critical in the management of AF.

TABLE 18. CHA_2DS_2-VASc Score, Adjusted Stroke Rates, and Stroke Prevention Therapy Recommendations for Nonvalvular Atrial Fibrillation and Flutter

CHA_2DS_2-VASc Score[a]	Incidence of Ischemic Stroke/ 100 Patient-Years[b]	Stroke Prevention Therapy[c]	
		Men	Women
0	0.2	None	N/A
1	0.6	Consider OAC	None
2	2.2	OAC	Consider OAC
3	3.2	OAC	OAC
4	4.8	OAC	OAC
5	7.2	OAC	OAC
6+	10.3	OAC	OAC

N/A = not applicable; OAC = oral anticoagulation.

[a]CHA_2DS_2-VASc scoring (maximum 9 points): One point each is given for heart failure, hypertension, diabetes mellitus, vascular disease (prior myocardial infarction, peripheral artery disease, aortic plaque), female sex, and age 65 to 74 years. Two points each are given for previous stroke/transient ischemic attack/thromboembolic disease and age ≥75 years.

[b]Data from Friberg L, Rosenqvist M, Lip GY. Evaluation of risk stratification schemes for ischaemic stroke and bleeding in 182 678 patients with atrial fibrillation: the Swedish Atrial Fibrillation cohort study. Eur Heart J. 2012;33:1500-10. [PMID: 22246443] doi:10.1093/eurheartj/ehr488

[c]Recommendations from January CT, Wann LS, Calkins H, et al. 2019 AHA/ACC/HRS focused update of the 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines and the Heart Rhythm Society. J Am Coll Cardiol. 2019;74:104-132. [PMID: 30703431] doi:10.1016/j.jacc.2019.01.011

Risk Stratification

Stroke prevention with oral anticoagulation depends on the patient's thromboembolic risk in the absence of obvious contraindications. Although several risk stratification scores are available, current guidelines recommend use of the CHA_2DS_2-VASc score in patients with nonvalvular AF. Adjusted stroke rates and recommendations for antithrombotic therapy based on the CHA_2DS_2-VASc score are shown in **Table 18**. The 2019 American College of Cardiology/American Heart Association/Heart Rhythm Society focused update on AF recommends anticoagulation to prevent stroke in patients with nonvalvular AF who have a CHA_2DS_2-VASc score of 2 or greater in men or 3 or greater in women. The American College of Chest Physicians guideline on antithrombotic therapy for AF recommends anticoagulation for patients with one or more non-sex CHA_2DS_2-VASc stroke risk factors (score of ≥1 in men or ≥2 in women). Antiplatelet therapy alone is no longer routinely used for stroke prevention in AF.

Anticoagulant Selection

Oral anticoagulation in patients with AF can be accomplished with a vitamin K antagonist (warfarin) or direct oral anticoagulant (DOAC) (**Table 19**). Anticoagulation in patients with valvular AF (moderate/severe mitral stenosis or mechanical valve prosthesis) should be obtained with warfarin; DOACs

TABLE 19. Anticoagulants Approved for Stroke Prevention in Atrial Fibrillation

Medication	Frequency	Type of AF	Cautions and Dosing
Warfarin (vitamin K antagonist)	Dose adjusted to INR	Valvular[a] or nonvalvular	Avoid in pregnancy
			Caution with idiopathic thrombocytopenic purpura, heparin-induced thrombocytopenia, liver disease, protein C or S deficiency
			Many drug and food interactions
Dabigatran (direct thrombin inhibitor)	Twice daily	Nonvalvular	Caution with use of P-glycoprotein inhibitors
			Reduce dose with CrCl 15-30 mL/min/1.73 m^2
Rivaroxaban (factor Xa inhibitor)	Once daily	Nonvalvular	Avoid with CrCl <30 mL/min/1.73 m^2, moderate liver impairment, use of strong P-glycoprotein inhibitors, or use of strong cytochrome P-450 inducers and inhibitors
			Reduce dose with CrCl 30-50 mL/min/1.73 m^2
Apixaban (factor Xa inhibitor)	Twice daily	Nonvalvular	Avoid with use of strong P-glycoprotein inhibitors or strong cytochrome P-450 inducers and inhibitors
			Reduce dose with two of the following criteria: creatinine level ≥1.5 mg/dL (133 µmol/L), age ≥80 y, or weight ≤60 kg (132 lb)
Edoxaban (factor Xa inhibitor)	Once daily	Nonvalvular	Avoid with use of strong cytochrome P-450 inducers and inhibitors
			Avoid with CrCl >95 mL/min/1.73 m^2 (reduced stroke prevention effectiveness). Reduce dose with CrCl 30-50 mL/min/1.73 m^2, weight ≤60 kg (132 lb), or concomitant use of verapamil or quinidine (potent P-glycoprotein inhibitors)

AF = atrial fibrillation; CrCl = creatinine clearance.

[a]Valvular atrial fibrillation refers to atrial fibrillation in the presence of moderate to severe mitral stenosis or mechanical valve prosthesis.

are not approved for use in valvular AF or those with any mechanical heart valve. DOACs are recommended in preference to warfarin in DOAC-eligible patients, including patients with AF and no valvular disease as well as patients with AF and aortic valve disease, mitral regurgitation, tricuspid regurgitation, or mild mitral stenosis in the absence of a mechanical prosthesis.

Warfarin

Dose-adjusted warfarin is an effective, low-cost therapy; however, its limitations include the need for frequent monitoring and adjustment and numerous food and drug interactions. The safety and efficacy of warfarin therapy depend on the time that the patient is in the therapeutic range (INR, 2-3). Management of warfarin overdose and warfarin-related bleeding is discussed in MKSAP 19 Hematology.

Direct-Acting Oral Anticoagulants

Four DOACs are approved for the prevention of stroke in AF. Dabigatran, an oral direct thrombin inhibitor, is superior to warfarin for the prevention of ischemic stroke and results in less intracranial bleeding. Patients taking dabigatran have a higher risk for gastrointestinal bleeding relative to warfarin and may experience dyspepsia. Rivaroxaban, a direct factor Xa inhibitor, is noninferior to warfarin in the prevention of stroke or systemic embolism and is associated with less intracranial and fatal bleeding. As with dabigatran, patients taking rivaroxaban have a higher risk for gastrointestinal bleeding compared with those taking warfarin. Apixaban, another oral factor Xa inhibitor, is superior to warfarin for stroke prevention and confers less risk for major bleeding, including intracranial and gastrointestinal bleeding. Edoxaban is noninferior to warfarin for stroke prevention and is associated with less major bleeding.

DOACs have shorter half-lives than warfarin; however, there are no quick, readily available serum assays to accurately determine anticoagulant activity. Andexanet alfa or 4-factor prothrombin complex concentrates are recommended for life-threatening bleeding due to rivaroxaban, apixaban, or edoxaban. Idarucizumab is a dabigatran-reversal agent available for emergency invasive or surgical procedures or in cases of uncontrolled or life-threatening bleeding.

Kidney and liver function should be evaluated before initiation of a DOAC and reevaluated at least annually. See MKSAP 19 Hematology for recommendations regarding DOAC dosing in patients with chronic kidney or liver disease.

Specific Populations

In patients with AF who have undergone percutaneous coronary intervention for acute coronary syndrome, both anticoagulant and antiplatelet therapies are necessary. Among these patients with a CHA_2DS_2-VASc score of 2 or greater, "double therapy" with clopidogrel or ticagrelor plus a DOAC is recommended over "triple therapy" with an oral anticoagulant, aspirin, and $P2Y_{12}$ inhibitor to reduce the risk for bleeding. In patients taking two or more antithrombotic agents, it is recommended that a proton pump

inhibitor be initiated and NSAIDs be avoided to reduce the risk of gastrointestinal bleeding.

In patients with AF and stable CAD, treatment with rivaroxaban alone is noninferior to rivaroxaban plus aspirin in the prevention of the composite end point of stroke, systemic embolization, myocardial infarction (MI), need for revascularization, or death from any cause. Rivaroxaban monotherapy also is associated with significantly less bleeding.

Rate-Only Versus Rate Plus Rhythm Control Treatment

The first priority among patients with AF is to control the ventricular rate. Rate control with a resting heart rate goal of less than 80/min is reasonable for symptomatic management of AF. A lenient rate-control strategy (resting heart rate <110/min) may be reasonable for asymptomatic patients without LV dysfunction. β-Blockers, calcium channel blockers, and, less often, digoxin are used to control the ventricular rate, although combination therapy may be necessary. Aside from resting heart rate assessment, evaluation of the heart rate with activity, such as with a 6-minute walk test, stress test, or 24-hour ambulatory ECG monitoring, may be performed.

Although historical trials have not proved a mortality benefit to maintaining sinus rhythm, numerous studies have demonstrated superior symptom treatment with rate plus rhythm control compared with rate control alone. Furthermore, because the long-term effects of rate-only control are unknown, rhythm control is often pursued in younger patients (aged <50 years) and may improve long-term clinical outcomes. A strategy of early rhythm control (within 1 year of diagnosis) among patients at high risk for adverse cardiovascular events was tested in the randomized EAST-AFNET 4 trial. High risk was defined as age older than 75 years or a previous transient ischemic attack or stroke, or meeting two of the following criteria: age older than 65 years, female sex, heart failure, hypertension, diabetes, severe CAD, chronic kidney disease, and LV hypertrophy. Early rhythm control (drugs or ablation) reduced the primary composite end point of cardiovascular death, stroke, or hospitalization for heart failure or acute coronary syndrome, compared with usual care. Rhythm control may require cardioversion in addition to antiarrhythmic therapy, which is guided by the patient's comorbid conditions and safety considerations. However, catheter ablation has been shown to be more effective than antiarrhythmic drugs, with an acceptable safety profile.

Nonpharmacologic Approaches to Atrial Fibrillation

Catheter ablation with pulmonary vein isolation is an effective rhythm control therapy in patients with recurrent symptomatic AF despite antiarrhythmic drug therapy. Catheter ablation is most effective in patients without significant left atrial enlargement and multiple comorbid conditions. One year after the procedure, 70% to 90% of patients with paroxysmal AF are symptom-free; however, success rates vary. Complications include thromboembolism (0.5%-1% risk), tamponade, and vascular complications (e.g., insertion hematoma, pseudoaneurysm, arteriovenous fistula, retroperitoneal bleeding). Longer-term complications, such as pulmonary vein stenosis, are uncommon.

AV node ablation is an option for patients with AF who have continued symptomatic tachycardia despite rate and rhythm control therapy. Therapeutic ablation of the AV node requires implantation of a permanent pacemaker. These patients remain in AF and still require anticoagulation.

Approximately 10% to 25% of patients with AF have contraindications to oral anticoagulation or discontinue therapy for various reasons, including bleeding events. In patients who are at moderate to high risk for stroke (CHA_2DS_2-VASc score ≥3), left atrial appendage occlusion to prevent stroke and systemic thromboembolism can be considered. Occlusion of the left atrial appendage can be achieved percutaneously with an implanted self-expanding device or with surgical closure. However, appropriate patient selection remains a challenge, and most patients undergoing percutaneous left atrial appendage occlusion require at least short-term oral anticoagulation while the device endothelializes. These patients also remain on long-term antiplatelet therapy.

Management in Patients With Heart Failure

AF complicates nearly 40% of cases of heart failure, and the combination of AF and heart failure dramatically worsens outcomes. Several clinical trials have demonstrated that aggressive efforts to achieve rhythm control in patients with AF and concomitant heart failure decrease morbidity and mortality. In patients with heart failure with reduced ejection fraction, recent clinical trials have shown that catheter ablation of AF is associated with a favorable effect on morbidity and mortality compared with medical therapy. Patient selection for catheter ablation remains important, and many of the trials enrolled selected patients.

Subclinical Atrial Fibrillation

The entity of subclinical AF is being increasingly recognized because of the growing prevalence of implantable cardiac devices and widespread availability of ambulatory ECG monitors (e.g., mobile continuous telemetry) and consumer devices (e.g., personal ECG monitors, smartwatches). Subclinical AF most commonly refers to AF that is asymptomatic and brief (definitions range from 20 seconds to <24 hours). Although definitive studies to guide management are lacking, there are several important considerations. First, episodes are frequently asymptomatic and short-lived; thus, symptom management and rate control are rarely required. Second, subclinical AF is associated with progression to AF; therefore, it is reasonable to consider traditional AF risk factor modification. Lastly, stroke risk in these patients is unclear. Studies have varied in their definition of subclinical AF and its associated stroke risk, and there is no consensus on the net clinical benefit of anticoagulation for subclinical AF. One notable exception is the detection of AF lasting more than 30 seconds among patients with embolic stroke of undetermined source (cryptogenic stroke);

anticoagulation is routinely indicated in these patients. Implantable loop recorders to detect subclinical AF may be indicated in selected patients with embolic stroke of undetermined source.

KEY POINTS

- Urgent cardioversion to sinus rhythm is indicated in patients with atrial fibrillation who have hypotension, acute myocardial ischemia, or decompensated heart failure, regardless of atrial fibrillation duration.
- Current guidelines recommend calculation of the CHA_2DS_2-VASc score for stroke risk stratification in patients with nonvalvular atrial fibrillation; patients with a CHA_2DS_2-VASc score of 2 or greater in men or 3 or greater in women should be treated with oral anticoagulation to prevent stroke.
- Direct-acting oral anticoagulants are recommended in preference to warfarin in patients with atrial fibrillation, excluding those with moderate to severe mitral stenosis or a mechanical valve prosthesis.
- In patients with atrial fibrillation, rate plus rhythm control offers superior symptom management compared with rate control alone.

Atrial Flutter

Atrial flutter is an organized macro-reentrant tachycardia with discrete regular atrial activity on ECG, usually with an atrial rate of 250/min to 300/min. Typical atrial flutter is characterized electrocardiographically by a sawtooth pattern with inverted flutter waves in leads II, III, and aVF and positive flutter waves in lead V_1 (**Figure 25**). Typical atrial flutter, the dominant form in patients without prior cardiac disease, is the result of counterclockwise reentry around the tricuspid annulus. Atypical flutter is primarily seen among patients with prior ablation for AF or prior cardiac surgery. In atypical flutter, the circuit is usually in other locations in the right and left atria.

Management of anticoagulation in the setting of chronic atrial flutter is similar to that for AF; however, a rhythm control strategy is favored in atrial flutter because rate control may be difficult and often requires high doses of more than one AV nodal blocker. Catheter ablation is the definitive treatment for typical atrial flutter because of a very high success rate (>95%) and low complication rate. Oral anticoagulation in patients with atrial flutter without ablation is approached in the same manner as in patients with AF.

KEY POINT

- Catheter ablation is the definitive treatment for typical atrial flutter, with a high success rate (>95%) and low risk for complications.

Ventricular Arrhythmias

Premature Ventricular Contractions

Premature ventricular contractions (PVCs) occur in up to 75% of healthy persons. Symptoms include palpitations or the perception of skipped beats. Forceful beats are caused by increased cardiac filling during the pause following the PVC. PVCs are

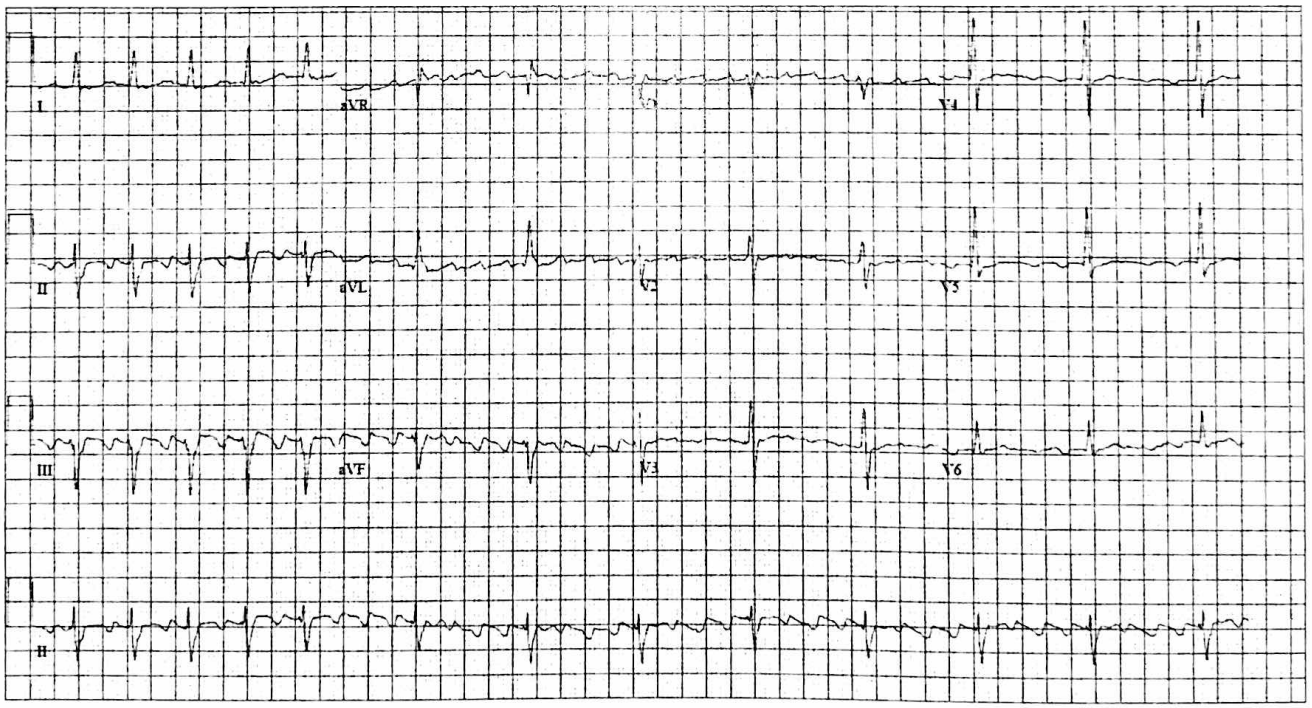

FIGURE 25. In this ECG demonstrating typical atrial flutter, negatively directed sawtooth waves are seen in the inferior leads (II, III, and aVF), and positive waves are seen in lead V_1. In the bottom rhythm strip, 2:1 and 4:1 conduction patterns are most easily seen.