

2 Arrhythmias

INTRODUCTION

The physiological impact of an arrhythmia depends on ventricular response rate, duration of arrhythmia, and underlying cardiac function. Bradyarrhythmias may decrease cardiac output owing to heart rate alone in patients with a relatively fixed stroke volume. Loss of atrial contraction may cause a dramatic increase in pulmonary artery pressures in patients with hypertension and diastolic dysfunction. Similarly, tachyarrhythmias can decrease diastolic filling time and reduce cardiac output, resulting in hypotension and possible myocardial ischemia. The impact of a given arrhythmia depends on the patient's cardiac physiology and function. Treatment is determined by the hemodynamic insult. In this chapter, a systematic approach to diagnosis and evaluation of predisposing factors is presented, followed by consideration of specific arrhythmias.

ARRHYTHMIA DIAGNOSIS

Basic Principles

The first principle in managing arrhythmias is to appropriately treat the patient, not the electrocardiogram (ECG). Accordingly, one must first decide whether the observed arrhythmia may be an artifact. If the arrhythmia is real and sustained, it must be determined whether it has important clinical consequences.

The next step is to establish the urgency of treatment. Clinical assessment includes evaluation of pulse, blood pressure, peripheral perfusion, and consideration of myocardial ischemia and/or congestive heart failure. If the patient loses consciousness or becomes hemodynamically unstable in the presence of a tachyarrhythmia

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other than sinus tachycardia, prompt cardioversion may be indicated regardless of anticoagulation status. If the patient is stable, there is often time to establish the rhythm diagnosis and decide upon the most appropriate treatment. Bradyarrhythmias produce less of a diagnostic challenge and treatment options are relatively straightforward.

The goals of antiarrhythmic therapy depend on the type of rhythm disturbance. The initial goal for the treatment of an arrhythmia is to stabilize the hemodynamics and ventricular response. The next goal is to restore sinus rhythm if possible. If restoration of sinus rhythm cannot be achieved, prevention of complications is important.

Classification of Arrhythmias

Arrhythmias are usually classified according to anatomic origin, either supraventricular or ventricular. The most common supraventricular arrhythmia is sinus tachycardia, followed by atrial fibrillation, ectopic atrial or junctional tachycardia, multifocal atrial tachycardia, atrioventricular (AV) nodal reentry tachycardias, and accessory pathway tachycardias. Ventricular arrhythmias are most commonly premature ventricular beats, ventricular tachycardia, and ventricular fibrillation.

It is sometimes useful to consider tachyarrhythmias from a treatment standpoint. Tachyarrhythmias that traverse the AV node can often be controlled by pharmacologically altering AV nodal conduction. Rhythms that traverse the AV node include atrial fibrillation and flutter, ectopic atrial and junctional tachycardias, multifocal atrial tachycardia, and AV nodal reentry tachycardias. Rhythms that do not utilize the AV node include accessory pathway tachycardias through a bypass tract, ventricular tachycardia, and ventricular fibrillation. When the arrhythmia does not utilize the AV node, slowing AV nodal conduction can be dangerous.

Rhythm Diagnosis

A comprehensive description of the diagnosis of arrhythmias is beyond the scope of this manuscript. A 12-lead ECG with a long rhythm strip and a previously obtained 12-lead ECG for comparison are ideal; If a previous ECG is not available, a systematic approach using a current 12-lead ECG is essential. An approach is outlined using the following five steps (Marriott, 1988).

1. LOCATE THE P-WAVE

P-waves are often best seen in leads II and V₁. Normal P-waves are upright in leads II, III, and aVF, and may be biphasic in leads II and V₁. If P-waves are present and always followed by a QRS complex, the rhythm is most likely sinus tachycardia, which usually occurs at a rate between 100 and 180 in adults. Ectopic atrial and junctional tachycardias often present with negative P-waves in leads II, III, and aVF. If P-waves are present and the rhythm is irregular, the rhythm is most likely atrial fibrillation. If the P-wave is buried in the QRS or ST segment, the rhythm is most likely AV nodal reentry tachycardia, which usually present with atrial rates from 140 to 220. If there are multiple P-waves followed by a single QRS, especially if the atrial rate is near 300, the rhythm is most likely atrial flutter. If no P-waves are present, the rhythm is most likely atrial fibrillation.

2. ESTABLISH THE RELATIONSHIP BETWEEN THE P-WAVE AND QRS

If there are more P-waves than QRS complexes, then AV block is present. If there are more QRS complexes than P-waves, the rhythm is likely an accelerated junctional or ventricular rhythm. If the relationship of the P-wave and QRS is 1:1, then measurement of the PR interval can yield useful diagnostic clues.

3. EXAMINE THE QRS MORPHOLOGY

A narrow QRS complex (<0.12 ms) indicates a supraventricular arrhythmia. A wide QRS complex can be either ventricular tachycardia or supraventricular tachycardia with either a pre-existing bundle branch block, or, less commonly, aberrant ventricular conduction or an antegrade accessory pathway.

4. SEARCH FOR OTHER CLUES

The clues to guide appropriate therapy depend on the situation. Carotid sinus massage increases AV block and can either break a supraventricular tachycardia or bring out previously undetected flutter waves. Any patient with a ventricular rate of exactly 150 beats per minute (bpm) should be suspected of having atrial flutter with 2:1 AV block. A rate greater than 200 bpm in an otherwise healthy adult should raise the suspicion of an accessory pathway. Severe left axis deviation (-60° to 120°) during tachycardia suggests a ventricular origin, as does AV dissociation, fusion beats (which result from

simultaneous activation of two foci, one ventricular and one supraventricular), and capture beats (beats that capture the ventricles and are conducted with a narrow complex, ruling out fixed bundle branch block). Grouped beating or more P-waves than QRS complexes suggests the possibility of second-degree AV block.

ATRIAL FIBRILLATION

Etiology and Pathophysiology

Atrial fibrillation is the most common sustained tachycardia encountered in clinical practice. It is estimated that 2.2 million Americans have paroxysmal or persistent atrial fibrillation. The prevalence increases with age and is more common in men than women (Go et al., 2001). The prevalence is 3.8% for persons greater than 60 years old and 9.0% for persons over 80 years old (Go et al., 2001).

Atrial fibrillation is characterized by uncoordinated atrial activity with an irregular ventricular response, usually rapid. Atrial fibrillation can occur with or without underlying structural heart disease or may be secondary to other predisposing conditions. Cardiac diseases associated with atrial fibrillation include hypertension, valvular heart disease, coronary artery disease (CAD), and cardiomyopathies. Atrial fibrillation has also been linked to alcohol ingestion, pulmonary embolism, hyperthyroidism, obstructive sleep apnea, chronic obstructive pulmonary disease, and is common following cardiac or thoracic surgery. Atrial fibrillation following an acute myocardial infarction (MI) carries a poor prognostic sign (Rathore et al., 2000).

Atrial fibrillation has been classified as paroxysmal, persistent, permanent, and lone (Fuster et al., 2001). Two or more episodes of atrial fibrillation has been defined as recurrent atrial fibrillation. Recurrent atrial fibrillation is further classified as either paroxysmal (terminates spontaneously) or persistent (sustained and does not convert to sinus rhythm without either pharmacological or electrical cardioversion). Permanent atrial fibrillation refers to long-standing atrial fibrillation (more than 1 year) in which cardioversion has not been indicated or attempted (Fuster et al., 2001). Lone atrial fibrillation refers to patients without structural heart disease or conditions predisposing to atrial fibrillation.

The mechanism of atrial fibrillation is not entirely clear. The conventional viewpoint was that multiple reentrant impulses wan-

dering throughout the atria created continuous electrical activity, the multiple wavelet hypothesis (Jalife, 2003). More recently, focal origin from electrically active tissue situated in the pulmonary veins have been identified (Haissaguerre et al., 1998). Other foci include the right atrium, superior vena cava, and coronary sinus (Chen et al., 1999; Haissaguerre et al., 1998; Jais et al., 1997). The distinction between these mechanisms is more than merely academic because origin from discrete foci presents the possibility of treatment either by ablating these foci or isolating them from the rest of the atrium.

Atrial fibrillation results in loss of effective atrial contraction and AV synchrony. The variation in the RR interval leads to changing diastolic filling intervals and therefore varying stroke volumes of AV synchrony may have an adverse impact on cardiac output.

Clinical Features

The symptoms of atrial fibrillation result from the rapidity and irregularity of the ventricular response and the loss of AV synchrony. The most common symptoms include palpitations, dyspnea, fatigue, lightheadedness, chest pain, and syncope. However, some patients with atrial fibrillation are completely asymptomatic.

The initial workup should include a complete history and physical exam, ECG, thyroid function tests, chest radiograph, complete blood count, serum electrolytes, and transthoracic echocardiogram. The history should focus on the onset, duration, frequency, symptoms, precipitating or reversible factors, and terminating events of each episode.

The ECG shows absent P-waves and an irregularly irregular rhythm. Fibrillatory waves may be seen in the inferior leads, at a rate of 300–700 bpm. The ventricular rate is usually between 100 and 180 bpm, but may be slower if there is AV nodal conduction disease, high vagal tone, or drugs affecting AV nodal conduction. The ventricular rate may be regular if the patient is ventricular-paced or there is an AV block. A chest x-ray is useful to evaluate the lungs, cardiac silhouette, and pulmonary vasculature.

All patients with new-onset atrial fibrillation should be evaluated by echocardiography. Echocardiography should be performed to evaluate the left and right atrial size, left and right ventricular size and function, valvular abnormalities, or pericardial disease. Transthoracic echocardiography can occasionally detect left atrial throm-

bus but the sensitivity is low. Transesophageal echocardiography (TEE) is the most sensitive and specific technique for diagnosing a thrombus in the left atrium, and should be considered before cardioversion or after a suspected embolic event.

Exercise testing should be performed on patients with suspected ischemic heart disease and those being considered for type Ic antiarrhythmic drug therapy (Fuster et al., 2001). Holter or event monitors may be used to capture the arrhythmia in patients with paroxysmal atrial fibrillation and to evaluate rate control.

Therapy

The three goals of therapy for atrial fibrillation are to control the rate, to restore and maintain normal sinus rhythm, and to prevent complications. Recent clinical trials have created controversy concerning whether rhythm control is superior to rate control. The Atrial Fibrillation Follow-Up Investigation of Rhythm Management (AF-FIRM) study enrolled 4060 patients older than 65 with at least one risk factor for stroke or death in a randomized, controlled trial comparing a rhythm control strategy to rate control (Wyse et al., 2002). Patients were randomized to antiarrhythmic drugs or cardioversion to restore sinus rhythm, or AV nodal blocking agents. The rate-control groups were anticoagulated indefinitely. The rhythm-control groups were anticoagulated, but at the discretion of their physician could be stopped if they were in normal sinus rhythm for longer than 4 weeks. The composite endpoint (death, disabling stroke, disabling anoxic encephalopathy, major bleeding, cardiac arrest) was not statistically different, but overall mortality was higher in the rhythm-control group, although this was not statistically significant. The rhythm-control group had more hospitalization, and in a 5-year follow-up only 63% was in normal sinus rhythm. Stroke rates averaged 1% per year in both groups, and occurred mostly in patients who stopped taking warfarin or who were subtherapeutic (Wyse et al., 2002).

The Rate Control versus Electrical Cardioversion for Persistent Atrial Fibrillation (RACE) study was a similar randomized, controlled trial comparing rhythm versus rate control in 522 patients with persistent atrial fibrillation, 90% of whom had risk factors for stroke (Van Gelder et al., 2002). Patients in the rate-control group received β -blockers, calcium channel blockers (CCBs), or digoxin,

and those in the rhythm group were cardioverted and maintained on sotalol. All patients received anticoagulation, but this could be discontinued in the rhythm-control group if sinus rhythm was achieved. There was no statistically significance in the composite endpoint (cardiovascular mortality, heart failure, thromboembolic events, bleeding, pacemaker implantation, drug side effects) in the rate-control (17.2%) and rhythm-control (22.6%) groups (Van Gelder et al., 2002). As with the AFFIRM trial, there were increased thromboembolic complications in the rhythm group, mainly among patients who discontinued anticoagulation therapy.

The Pharmacological Intervention in Atrial Fibrillation study was a rate versus rhythm trial enrolling 252 patients with persistent symptomatic atrial fibrillation, with symptomatic improvement as the primary endpoint (Hohnloser et al., 2000). The rate-control group was given diltiazem, whereas the rhythm group was given amiodarone; all patients were anticoagulated. Quality of life and symptoms improved in both groups to the same extent. The rhythm group had better exercise tolerance. More patients in the rhythm-control group were hospitalized and they suffered more drug side effects.

The Strategies of Treatment of Atrial Fibrillation pilot study examined the effects of rate versus rhythm control on death, cardiovascular events, cardiopulmonary resuscitation, or systemic emboli (Carlsson et al., 2003). The rate-control group received an AV nodal blocking medication (β -blocker, CCB, digoxin). The rhythm-control group received amiodarone or some other class I antiarrhythmic, or electrical cardioversion. Both groups were anticoagulated. There was no statistically significant difference in either the primary endpoint or the secondary endpoints (syncope, bleeding, worsening heart failure, quality of life). The rhythm-control group required more frequent hospitalizations with longer lengths of stay. At a 3-year follow-up, only 23% of the rhythm-control group was in sinus rhythm (Carlsson et al., 2003).

Based on these trials, either a rate-control or a rhythm-control strategy can be chosen, individualized to a particular patient. The initial priority in a patient presenting with atrial fibrillation is to control the ventricular rate acutely. This can be accomplished with either β -blockers or CCBs. If very rapid control is required, intravenous β -blockade with metoprolol (5 mg intravenously every 5 minutes up to three doses) or esmolol (500 μ g/kg bolus and 50 μ g/kg per

minute infusion titrated up in 50 $\mu\text{g/kg}$ per minute increments every 3 to 5 minutes up to 200 $\mu\text{g/kg}$ per minute), followed by oral therapy can be used. Risks include hypotension, bronchospasm, and negative inotropic effects. Intravenous calcium channel blockade with diltiazem (10–20 mg intravenously over 2 minutes and then at 5–20 mg per hour intravenously) or verapamil (2.5 mg intravenously over 2 minutes, repeated every 15 minutes up to 15 mg), followed by oral therapy is equally acceptable. Risks include hypotension and heart failure. Digoxin is a second-line alternative that is much better for chronic than acute rate control, and is recommended in patients with heart failure (Snow et al., 2003). Digoxin can be loaded intravenously (1 mg load, usually 0.25 mg intravenously every 6 hours but can be given as 0.5 mg once followed by 0.25 mg every 3 hours for two doses) if necessary. Measurement of levels should be done at steady-state, and is not especially helpful in atrial fibrillation except in patients with suspected toxicity. Maintenance doses range from 0.125 to 0.375 mg per day, and require adjustment for renal insufficiency.

Chronically, rate control is needed to avoid the symptoms and hemodynamic instability caused by a rapid ventricular response. β -Blockers (atenolol, metoprolol, propranolol, esmolol), nondihydropyridine calcium antagonists (verapamil, diltiazem), and digoxin slow AV nodal conduction and are the recommended pharmacological agents for rate control. The current American College of Cardiology/American Heart Association/European Society of Cardiology (ACC/AHA/ESC) guidelines recommend dose titration to a resting heart rate of 60–80 and 90–115 bpm during exercise (Fuster et al., 2001). Digoxin provides rate control at rest but not with exercise, and is used in combination with β -blockers or CCBs or alone when they are not tolerated.

Hemodynamically unstable patients require emergent cardioversion, and those with acute heart failure or angina should be considered for urgent cardioversion. Electrical cardioversion may be more effective when the defibrillator pads are placed in an anterior–posterior orientation to direct the current through the atria.

Rhythm control is achieved either through synchronized external cardioversion or pharmacological cardioversion. The risk of thromboembolism is the same for electrical and pharmacological cardioversion. If the duration of atrial fibrillation less than 48 hours and the patient is at low thromboembolic risk, the patient should be heparin-

ized, cardioverted, and given aspirin for 1 month. A patient at high risk (mitral valve disease, previous thromboembolism, severe left ventricular [LV] dysfunction) should be anticoagulated for 1 month before elective cardioversion. For patients presenting in atrial fibrillation for more than 48 hours or of unknown duration, intravenous heparin and oral warfarin should be initiated upon presentation. TEE can be used to evaluate for left atrial thrombus. If no thrombus is visualized, the patient can be safely cardioverted and then anticoagulated for 1 month (Manning et al., 1993) because recovery of atrial mechanical function may be delayed despite restoration of sinus rhythm. If a thrombus is seen, the patient should be anticoagulated for at least 3–4 weeks prior to elective cardioversion.

The use of pharmacological cardioversion should be based on the duration of the atrial fibrillation, presence or absence of structural heart disease, and persistent symptoms on rate-control agents. Before instituting an antiarrhythmic agent, reversible causes (hyperthyroidism, hypertension, heart failure, cardiac surgery, pulmonary embolism) need to be addressed.

Antiarrhythmic agents are divided into classes according to mechanism of action. Class I agents are sodium channel blockers and prolong the QT interval, leading to the potential for proarrhythmia and torsades de pointes. Class Ia agents, which include quinidine, procainamide, and disopyramide, block potassium channels as well. Quinidine can cause sinus and AV nodal blockade, in addition to its proarrhythmic effects. When initiating this agent the patient should have continuous ECG monitoring. Non-cardiac effects include abdominal cramping, nausea, and diarrhea, and cinchonism, a constellation of symptoms (tinnitus, hearing loss, blurred vision, delirium, confusion, and psychosis) associated with high plasma levels of the drug. Procainamide side effects include lupus-like syndrome, nausea, vomiting, dizziness, psychosis, headache, depression, vasculitis, myalgias, fever, and pancytopenia or agranulocytosis, which may be life-threatening. Procainamide can also lengthen the PR interval in patients with AV conduction disease. The drug has an active metabolite (*N*-acetylprocainamide), and should be adjusted in renal or hepatic impairment. Disopyramide has negative inotropic effects and should be avoided in patients with heart failure, and is associated with anticholinergic symptoms and should not be used in patients with glaucoma, myasthenia gravis, or urinary reten-

tion. Disopyramide needs to be adjusted for renal and hepatic impairment.

Class Ic antiarrhythmic agents (flecainide, propafenone, moricizine) block sodium channels but have less profound effects on repolarization. All class Ic agents have a negative inotropic effect and therefore are contraindicated in patients with heart failure. Extracardiac effects of flecainide include dizziness, headache, blurred vision, and ataxia. Propafenone has β -blocking effects in addition to class Ic antiarrhythmic properties, and should be avoided in patients with reactive airway diseases and sinus node dysfunction. Other common side effects include nausea, metallic taste, increased liver enzymes, dizziness, and constipation.

Class III antiarrhythmic agents (amiodarone, sotalol, dofetilide, ibutilide) are potassium channel blockers and prolong repolarization, action potential durations and refractory periods. All class III agents increase the QT interval and may precipitate torsades de pointes. Amiodarone blocks potassium, sodium, and calcium channels, and α - and β -receptors. Amiodarone is highly lipid soluble and accumulates in high concentrations in adipose tissue and highly perfused organs, such as the lung, liver, and skin. Because of the extensive accumulation the elimination half-life is long after discontinuation of the drug. The adverse effects of amiodarone therapy include pulmonary fibrosis, thyroid dysfunction, AV node blockade, hepatotoxicity, corneal microdeposits, optic nerve injury, gray-blue skin discoloration, tremor, ataxia, and peripheral neuropathy. Amiodarone interacts with other drugs, notably warfarin and digoxin, mandating dose adjustments if taken together. Liver function tests, thyroid function tests, and pulmonary function should be monitored periodically in patients on amiodarone (Goldschlager et al., 2000). Sotalol is a racemic mixture of D- and L-isomers that has class III and β -blocker actions. Side effects are largely due to the β -blockade, mandating caution in patients with reactive airway disease, sinus bradycardia, AV block, and uncontrolled heart failure. Sotalol has proarrhythmic effects and should not be administered to patients with prolonged QT intervals; initiation of sotalol is performed in a hospital setting with continuous cardiac monitoring. Sotalol is excreted by the kidneys and the dose should be adjusted in renal impairment. Dofetilide blocks the rapid component of the delayed rectifier potassium current, and prolongs the repolarization

and refractory period in the atrium and ventricles without affecting the conduction system. Dofetilide prolongs the QT interval, and poses a risk of developing torsades de pointes, which is greatest within the first 3 days of drug initiation, so the drug is started in the hospital with continuous cardiac monitoring. Dofetilide is renally eliminated and interacts with a number of drugs, including verapamil, cimetidine, diuretics, ketoconazole, macrolide antibiotics, trimethoprim, triamterene, metformin, amiloride, and megestrol. Ibutilide is an intravenous class III antiarrhythmic drug that is used to terminate acute atrial fibrillation acutely. One milligram of ibutilide should be infused over 10 minutes. Termination of the arrhythmia should occur with 60 minutes of initiating the dose, and if the arrhythmia does not terminate the dose may be repeated. Like all class III agents, ibutilide can lengthen the QT interval and precipitate torsades de pointes, and so continuous ECG monitoring for 6 hours after drug administration is mandatory, even if sinus rhythm has been restored.

The choice of an antiarrhythmic agent depends on the clinical setting. Propafenone or flecainide are recommended as first-line drugs for pharmacological cardioversion in patients without structural heart disease, although amiodarone, sotalol, and dofetilide are alternative agents (Fuster et al., 2001). Sotalol and amiodarone can be used for adrenergically mediated atrial fibrillation, and disopyramide is suggested for vagally induced atrial fibrillation. In patients with structural heart disease, amiodarone and sotalol are recommended as the first line drugs. Class Ic antiarrhythmic agents (flecainide, encainide, moricizine) should be avoided in patients with coronary heart disease owing to the increased mortality shown in the Cardiac Arrhythmia Suppression Trial (CAST II Investigators, 1992; Echt et al., 1991). Amiodarone is recommended for patients with heart failure and atrial fibrillation; dofetilide is an alternative (Fuster et al., 2001).

The other important issue in the management of patients with atrial fibrillation is prevention of complications, most notably stroke. Atrial fibrillation is a risk factor for stroke, but varies among patients. The annual risk in the Framingham study was 4.2% but may be higher for patients with more than one risk factor (Wolf et al., 1978). Two studies, Atrial Fibrillation Investigation (AFI) (Atrial Fibrillation Investigators, 1994) and Stroke Prevention in Atrial Fibrillation (SPAF)

(Hart et al., 1999) identified individual risk factors that increased the risk of stroke in patients with atrial fibrillation. Risk factors for stroke in the AFI study included previous stroke, hypertension, diabetes, and advanced age. SPAF correlated stroke risk with previous stroke, females over the age 75, systolic hypertension, and low ejection fraction (EF). To simplify the system, Gage et al. (2001) combined the risk factors from both studies and devised a point system called CHADS2. Two points were given to a history of previous stroke, and all other risk factors were given 1 point. A score of 0–1 was identified as low risk for stroke and warfarin was not recommended. A score of 2–3 was moderate risk, 4–6 was high risk. Warfarin was recommended for both the moderate and high-risk groups.

The ACC/AHA/ESC developed their own risk-based approach to antithrombotic therapy in patients with atrial fibrillation (Table 1). These guidelines recommend warfarin for patients with atrial fibrillation and valvular disease, previous stroke, or at least one risk factor (heart failure, female over the age of 75, low EF, diabetes, hypertension). Aspirin is recommended for patients less than 60 years old with no risk factors with or without heart disease and patients older than 60 years with no heart disease and no risk factors. The target international normalized ratio range for nonvalvular atrial fibrillation is 2–3, and 2.5–3.5 for valvular disease (Fuster et al., 2001).

Whether anticoagulation can be stopped in patients who have converted to sinus rhythm is a difficult and unresolved question. The results of the rate-control versus rhythm-control strategies described earlier suggest that patients who have been converted to sinus rhythm may have paroxysmal episodes of atrial fibrillation that go undetected. On the other hand, anticoagulation poses a risk of hemorrhage. In general, chronic anticoagulation with warfarin is desirable unless the patient is a low risk for stroke or the drug is contraindicated (Snow et al., 2003).

Nonpharmacological therapies (surgical ablation, percutaneous catheter ablation) are indicated for patients who are symptomatic and refractory to medical therapy. Foci in the pulmonary veins, superior vena cava, right and left atrium or coronary sinus can be ablated percutaneously using a radiofrequency catheter. The risk of recurrence after focal ablation is currently about 30–50%, and many patients still require antiarrhythmic therapy after ablation (Fuster et al., 2001). Complications of catheter ablation include

Table 1
Risk-Based Approach to Antithrombotic Therapy in Patients With Atrial Fibrillation

<i>Patient features</i>	<i>Antithrombotic therapy</i>
Age <60, no heart disease	Aspirin 325 mg per day or no therapy
Age <60, heart disease but no risk factors ^a	Aspirin 325 mg per day
Age >60, no risk factors ^a	Aspirin 325 mg per day
Age >60 with diabetes or CAD	Warfarin (INR 2–3)
Age >75, especially women	Addition of aspirin, 81–162 mg per day is optional
Heart failure (EF <35%)	Warfarin (INR approximately 2)
Thyrototoxicosis	Warfarin (INR 2–3)
Hypertension	
Rheumatic heart disease	Warfarin (INR 2.5–3.5)
Prosthetic heart valves	
Prior thromboembolism	
Persistent atrial thrombus on TEE	

^aRisk factors for thromboembolism include heart failure, ejection fraction less than 35%, and a history of hypertension.

INR, international normalized ratio; CAD, coronary artery disease; EF, ejection fraction; TEE, transesophageal echocardiography.

Adapted from Fuster et al. (2001).

pulmonary vein stenosis, pericardial effusion and tamponade, phrenic nerve paralysis, and systemic embolism. Catheter ablation of the AV node with insertion of a permanent pacemaker is another option. A meta-analysis concluded that AV nodal ablation and pacemaker implantation improved symptoms, quality of life, exercise duration, and LV function (Wood et al., 2000). Surgical ablation, the Maze procedure, is an invasive approach that requires a thoracotomy and general anesthesia. This option is usually employed in patients requiring open heart surgery for other indications.

SUPRAVENTRICULAR TACHYCARDIA

Sinus Tachycardia

Sinus tachycardia is a rhythm that arises from the sinoatrial (SA) node with a heart rate of more than 100 bpm. It is usually a physiological response to an underlying cause, which can include pain, anxiety, fever, exercise, hyperthyroidism, volume depletion, hypotension, pulmonary embolism, MI, anemia, or infection. Certain illicit drugs, such as cocaine, amphetamines, and ecstasy can precipitate this arrhythmia. Other stimulants (caffeine, alcohol, nicotine) and prescribed medications (atropine, catecholamines, aminophylline, doxorubicin, daunorubicin) can induce sinus tachycardia.

Occasional patients may have inappropriate sinus tachycardia, an uncommon arrhythmia that occurs most commonly in young women, a disproportionate number from the health care profession. The mechanism is unclear; studies have suggested that there is abnormal sinus node automaticity or excess sympathetic and reduced parasympathetic tone (Bauernfeind et al., 1979; Blomstrom-Lundqvist et al., 2003). Diagnostic criteria include exclusion of secondary causes.

Patients may be asymptomatic or may complain of palpitations, lightheadedness, or dizziness. The P-waves have the same sinus morphology (upright in leads I, II, and III). With increasing heart rate, the PR interval decreases. The QRS complex is narrow. Vagal maneuvers (carotid massage or Valsalva maneuver) may help in differentiating sinus tachycardia from other paroxysmal supraventricular tachycardias.

The first priority in the treatment of sinus tachycardia is to identify the underlying cause. Once the cause is identified, treatment can

be tailored to that cause. Pharmacological therapy can be used in certain situations. β -Blockers may be used to treat sinus tachycardia resulting from anxiety, hyperthyroidism, and MI. For in appropriate sinus tachycardia, β -blockers are first-line therapy, with CCBs as an alternative (Blomstrom-Lundqvist et al., 2003) if β -blockers are contraindicated. If patients are refractory to medical therapy, sinus node modification by catheter ablation is an option.

Focal (Ectopic) Atrial Tachycardia

Repetitive focal atrial tachycardia is thought to be caused by enhanced automaticity arising from a single atrial focus. This arrhythmia is seen in patients with organic heart disease, lung disease, MI, infection, electrolyte disturbances (hypokalemia), and hypoxemia. Medications that can enhance automaticity include digoxin and theophylline. Drugs of abuse such as cocaine and alcohol can also induce this arrhythmia.

On the ECG, the P-wave morphology will be consistent but different from the sinus P-waves. The QRS complex is usually narrow. There is often a progressive acceleration in the atrial rate (warm up) at the beginning followed by a gradual decrease at the end of the arrhythmia (cool down).

For acute treatment in hemodynamically stable patients, either adenosine, β -blockers or conversion with intravenous antiarrhythmics from classes Ia, Ic, or III is recommended (Blomstrom-Lundqvist et al., 2003). Hemodynamically unstable patients should be cardioverted. If rate regulation only is needed in the acute setting, intravenous β -blockers, verapamil, or diltiazem is indicated. Digoxin can also be used as long as the arrhythmia is not the result of digoxin toxicity. For prophylactic therapy to prevent recurrence, β -blockers and CCBs are the treatment of choice. Disopyramide, flecainide, propafenone, sotalol, and amiodarone are alternatives for prophylactic treatment (Blomstrom-Lundqvist et al., 2003). Class Ic antiarrhythmics should not be given to patients with CAD. For symptomatic patients refractory to medical therapy, catheter ablation is recommended.

Multifocal Atrial Tachycardia

Multifocal atrial tachycardia (MAT) usually occurs in the acutely ill, elderly patient, or in those with pulmonary disease (McCord &

Borzak, 1998). MAT is also associated with diabetes, hypokalemia, hypomagnesemia, chronic kidney disease, hypoxia, acidosis, hypercapnia, and certain medications. MAT is diagnosed by the presence of three or more different P-wave morphologies on one ECG with an irregularly irregular rhythm. The most useful therapy for MAT is to treat the underlying causes, including hypoxemia and hypercapnia, myocardial ischemia, congestive heart failure, or electrolyte disturbances. β -Blockers and CCBs can slow an excessive ventricular rate (Levine et al., 1985). These agents should be used cautiously in patients with known congestive heart failure or reduced LV function.

AV Nodal Reentry Tachycardia

Atrioventricular nodal reentry tachycardia (AVNRT) is the most common paroxysmal supraventricular tachycardia, accounting for about 60% of all supraventricular arrhythmias (Kastor, 1994). It tends to be more common in women than men. Symptoms emerge most commonly in young adults, although they can occur at any age. Most patients with AVNRT do not have structural heart disease.

Dual AV nodal pathways with different conduction velocities and refractory periods are usually present, setting up the substrate for reentry (Mazgalev & Tchou, 2000). The slow pathway has a short refractory time, and the fast pathway has a longer refractory time. A normal sinus beat travels down both fast and slow pathways. In the most common variant, slow-fast AVNRT, a critically timed premature beat finds that the fast pathway is still refractory, and conducts down the slow pathway. If the fast pathway has recovered, the impulse can then be conducted retrograde up the fast pathway to the atrium, creating a re-entrant circuit. The uncommon fast-slow AVNRT has antegrade conduction down the fast pathway and retrograde conduction up the slow pathway.

The symptoms of AVNRT are related to the rapid heart rate and include palpitations, lightheadedness, dizziness, and sometimes syncope. Some patients may experience chest pain or dyspnea. The heart rate ranges from 120 to 220 bpm. The P-wave can occur immediately before or after the QRS complex, or may not be seen on the ECG because of near-simultaneous retrograde atrial and antegrade ventricular activation. If P-wave occurs immediately after the QRS, there may be a pseudo-R-wave in V1 or pseudo-S-wave leads II, III,

and aVF reflecting retrograde conduction. In the less common fast-slow AVNRT, the P-wave may occur just before the next QRS.

Carotid sinus massage or other vagal maneuvers may convert AVNRT to normal sinus rhythm. Adenosine 6 to 12 mg intravenously is the preferred initial drug treatment because its extremely short half-life minimizes side effects. The 12 mg dose may be repeated if necessary. Urgent cardioversion may be necessary with circulatory insufficiency. The AV node action potential is calcium channel-dependent, which make verapamil or diltiazem very effective in terminating this arrhythmia. β -Blockers are also effective.

For chronic therapy in patients with frequent symptomatic episodes, β -blockers are preferred because they suppress the initiating premature atrial contractions. CCBs and digoxin can also be used. In patients who do not respond to AV nodal blocking agents and who do not have structural heart disease, flecainide or propafenone are the recommended antiarrhythmic drugs of choice (Blomstrom-Lundqvist et al., 2003).

Radiofrequency catheter ablation of the slow pathway is a curative treatment modality in patients with AVNRT. In the North American Society for Pacing and Electrophysiology prospective registry, the success rate was 96.1%, with AV block as a complication in only 1% (Scheinman & Huang, 2000). Based on these results, and with appropriate selection by physicians, many patients with recurrent AVNRT are choosing catheter ablation therapy over antiarrhythmic therapy.

Atrioventricular Reciprocating Tachycardia

Atrioventricular reciprocating tachycardia (AVRT) is characterized by an extra-nodal accessory bypass tract connecting the atrium to the ventricles. Approximately 30% of patients with supraventricular tachycardia will be found to have an accessory pathway (Kastor, 1994).

Conduction through these accessory pathways can be from the atrium to the ventricles (antegrade conduction) or from the ventricles to the atrium (retrograde conduction). When conduction goes down the AV node and back up the bypass tract, the QRS complex is narrow and conduction is termed *orthodromic* (Kastor, 1994). When conduction goes down the bypass tract and back up the AV

node, the QRS complex is wide and conduction is termed *antidromic* (Kastor, 1994).

Accessory pathways that are capable of antegrade conduction pre-excite the ventricles. The characteristic ECG finding of this pre-excitation is the delta wave. Patients with a delta wave and an AVRT are said to have Wolff-Parkinson-White (WPW) syndrome. There are no characteristic ECG findings when the accessory pathway conducts in the retrograde direction. These pathways are termed *concealed accessory pathways*.

In AVRT, a critically timed premature atrial or ventricular beat initiates a reentrant tachycardia. Orthodromic AVRT uses the AV node and His-Purkinje system to conduct the impulse to the ventricles; the QRS complex is narrow, and the heart rate ranges from 150 to 250 bpm. In antidromic AVRT, the impulses are conducted to the ventricle through the accessory pathway, generating a wide QRS complex. Antidromic AVRT is faster because of the relatively short refractory period of the accessory pathway.

Wolff-Parkinson-White Syndrome

WPW syndrome is a pre-excitation syndrome characterized by an accessory pathway (bundle of Kent) that bypasses the AV node and activates the ventricles prematurely. Most patients with WPW have otherwise normal hearts, but some have congenital anomalies, such as Ebstein's anomaly, septal defects, transposition of the great vessels, and a familial form of hypertrophic cardiomyopathy. The prevalence of WPW syndrome is approximately 0.1–0.3% of the general population. WPW is twice as common in men as in women.

The ECG findings include a shortened PR interval, delta wave and a widened QRS complex. The PR interval is short owing to the rapid AV conduction through the accessory pathway, bypassing the delay in the AV node. The delta wave is produced by the slow early activation of the ventricles by the accessory pathway. The widened QRS complex results from fusion of early ventricular activation by the accessory pathway and activation from the impulses conducted through the AV node and infranodal system.

Most patients with WPW syndrome present with symptoms of tachyarrhythmias. Tachyarrhythmias associated with WPW syndrome include AVRT, atrial fibrillation, atrial flutter, and ventricular fibrillation. Approximately 10–30% of patients with WPW will

develop atrial fibrillation (Campbell et al., 1977). In those patients, AVRT usual precedes atrial fibrillation. The impulses generated during atrial fibrillation can conduct antegrade down the accessory pathway, and can be transmitted at very high rates (>250 bpm) due to the short refractory time of the accessory pathway.

The ECG in atrial fibrillation with WPW is characteristic. The diagnosis is made by the irregularly irregular rhythm, which indicates atrial fibrillation, and the varying width of the QRS complexes, which is caused by varying degrees of fusion resulting from antegrade conduction down both the normal conducting system and the bypass tract. Some of the R-R intervals can be extremely short, less than 250 ms. Rapid atrial fibrillation in WPW is very dangerous because it can deteriorate to ventricular fibrillation and sudden cardiac death.

THERAPY

Pharmacological treatment of AVRT must be tailored to the electrophysiological properties of the arrhythmia. Therapy of orthodromic accessory pathway reentrant tachycardias entails AV nodal blockade with vagal maneuvers, IV adenosine, and CCBs (Blomstrom-Lundqvist et al., 2003). Second-line drugs include intravenous procainamide and β -blockers. Chronic therapy for orthodromic AVRT usually involves administration of class Ic antiarrhythmic drugs (flecainide, encainide).

For antidromic accessory pathway reentrant tachycardias, intravenous procainamide is the drug of choice because it slows conduction down the accessory pathway. Atrial flutter or fibrillation with antidromic conduction is a dangerous situation due to the potential for extremely rapid conduction down the accessory pathway with resultant rapid ventricular rates. In this situation, the ventricular rate is modulated by competition between AV nodal conduction and conduction down the bypass tract. Drugs that block the AV node such as digoxin, verapamil, or diltiazem can thus increase ventricular rate and lead to the potential for ventricular fibrillation. In both orthodromic and antidromic AVRT, cardioversion is indicated for hemodynamic collapse.

For chronic therapy of antidromic AVRT, class Ic antiarrhythmic drugs are recommended (Blomstrom-Lundqvist et al., 2003). Amiodarone and class Ia agents can be used as second-line therapy.

Catheter ablation is potentially curative, and has a low complication rate (Jackman et al., 1991; Wang & Yao, 2003). Catheter ablation was given a class I recommendation by the ACC/AHA/ESC for patients with WPW syndrome and symptomatic arrhythmias, atrial fibrillation or poorly tolerated AVRT (Blomstrom-Lundqvist et al., 2003). The same group gave catheter ablation a class IIa recommendation for asymptomatic patients in high-risk occupations. Many patients with recurrent arrhythmias choose catheter ablation over lifelong antiarrhythmic medication, although recurrences after ablation do occur (Wang & Yao, 2003).

Junctional Tachycardia

Junctional tachycardias are rare and usually benign. They result from increased automaticity arising from a high junctional focus or triggered activity (Lee et al., 1999). Nonparoxysmal junctional tachycardia is usually caused by digoxin toxicity, hypokalemia, theophylline, inferior wall MIs, myocarditis, catecholamine excess, or postcardiac surgery.

The ECG shows a narrow complex tachycardia with absent P-waves and a heart rate ranging from 70 to 110 bpm. Onset is usually gradual with a typical “warm-up” and “cool-down” pattern. If digoxin toxicity is the etiology, the ECG may show a second-degree Mobitz type I block.

Management for junctional tachycardia is to eliminate and correct the underlying cause. Occasionally, loss of AV synchrony leads to decreased cardiac output. Overdrive atrial pacing at an appropriate rate can improve AV synchrony and cardiac output. Persistent junctional tachycardia can be treated with β -blockers or CCBs (Lee et al., 1999).

VENTRICULAR TACHYCARDIA

Ventricular tachyarrhythmias can be classified as benign or malignant. The chief distinction, in addition to duration and hemodynamic consequences, is the presence of significant structural heart disease. This distinction is especially important when evaluating premature ventricular contractions (PVCs) and nonsustained ventricular tachycardia (NSVT). In patients without structural heart disease, the risk of sudden death or hemodynamic compromise is minimal, and therapy is rarely necessary in the absence of symp-

toms. In patients with CAD, a history of MI, or cardiomyopathy, PVCs may indicate the potential for malignant ventricular tachyarrhythmias and merit prompt and thorough assessment. Prompt evaluation for and reversal of precipitating factors such as ischemia and electrolyte abnormalities are indicated.

Ventricular tachycardia can be monomorphic or polymorphic, sustained or nonsustained. Sustained ventricular tachycardia is defined as persisting for longer than 30 seconds; nonsustained has at least three or more ventricular beats but lasts less than 30 seconds.

The signs and symptoms of ventricular dysrhythmia range from palpitations, diaphoresis, dizziness, lightheadedness, shortness of breath, chest pain, pre-syncope, syncope, and sudden cardiac death. Some patients may be completely asymptomatic. A complete history and physical exam should be performed on all patients with ventricular dysrhythmias. The patient should be questioned about a family history of sudden cardiac death and evaluated for risk factors of CAD.

Ventricular tachycardia is a wide complex rhythm that must be distinguished from supraventricular tachycardia with aberrant conduction. Clues that suggest a ventricular origin include AV dissociation, fusion beats (which result from simultaneous activation of two foci, one ventricular and one supraventricular), and capture beats (beats that capture the ventricle and are conducted with a narrow complex, ruling out fixed bundle branch block), as well as severe left axis deviation (-60° to 120°). A more systematic approach to distinguish ventricular tachycardia from a wide-complex supraventricular tachycardia was outlined by Brugada et al. (1991) The diagnosis is ventricular tachycardia if there is absence of the RS complex in all precordial leads, R to S interval is greater than 100 ms in one precordial lead, AV dissociation, or characteristic morphology in leads V_1 , V_2 , and V_6 . If not, the arrhythmia is most likely supraventricular tachycardia with aberrant conduction.

Sustained monomorphic ventricular tachycardia is a reentrant rhythm most commonly occurring more than 48 hours after an MI, or in the setting of cardiomyopathy. Initial management of sustained monomorphic ventricular tachycardia with a history of structural heart disease depends on its rate, duration, and hemodynamic status. Unstable ventricular tachycardia is an indication for prompt defibrillation. Hemodynamically stable patients with a risk of imminent

circulatory collapse may be treated with an antiarrhythmic such as intravenous amiodarone. Current Advanced Cardiac Life Support guidelines consider lidocaine and intravenous procainamide alternative choices. If the arrhythmia recurs, intravenous antiarrhythmic drug therapy, with either amiodarone, lidocaine, or procainamide, should be initiated.

Enthusiasm for the use of chronic antiarrhythmic agents to prevent ventricular arrhythmias was considerably dampened after the CAST, which showed an increase in mortality in patients receiving flecainide or encainide in patients with CAD (Echt et al., 1991). There has been concern that other antiarrhythmic agents could have the same proarrhythmic effects. Available data suggests that amiodarone and sotalol are the most effective antiarrhythmic drugs for preventing sustained ventricular tachycardia.

Clinical trials comparing insertion of automated implantable cardioverter defibrillators (AICD) to antiarrhythmic drug therapy have generally shown a benefit for AICD placement. In high-risk patients (NSVT, prior Q-wave MI, EF of 35% or less, inducible sustained ventricular tachycardia not suppressed by procainamide at electrophysiological study), the Multicenter Automatic Defibrillator Implantation Trial (MADIT) study showed significantly improved survival with AICD compared to conventional medical therapy (Moss et al., 1996). Similarly, the Antiarrhythmics Versus Implantable Defibrillator (AVID) study showed that patients resuscitated from ventricular fibrillation or with hemodynamically significant ventricular tachycardia with EF of 40% or less had improved survival with AICD compared to antiarrhythmic therapy (amiodarone in more than 80%) (AVID Investigators, 1997).

AICD placement appears to be effective as primary prevention as well. The MADIT-II trial demonstrated that prophylactic placement of an implantable cardioverter defibrillator (ICD) in patients with LVEF of 30% or less after MI improved survival (Moss et al., 2002). The timing of ICD implantation however, is uncertain. In the recent Defibrillator in Acute Myocardial Infarction, placement of an ICD immediately after an MI did not reduce all-cause mortality (Hohnloser et al., 2004), and analysis of MADIT-II demonstrated that patients with a remote MI (at least 18 months previous) benefited greatly from the ICD, whereas those with a more recent MI (<18 months) did not (Greenberg et al., 2004). Data from the Sudden

Cardiac Death-Heart Failure trial also showed a survival benefit in patients with either an ischemic or a non-ischemic cardiomyopathy and EF less than 35% after implantation of an AICD compared to amiodarone (Bardy et al., 2005). Because of the outcomes of these trials, implantable defibrillators are recommended for survivors of sudden cardiac death and patients with a previous MI and LVEF of less than 35%.

The challenge in selecting patients for AICD implantation is that identification of the highest risk subgroups leads to very cost-effective use of devices but identifies only a small proportion of the 300,000 sudden cardiac deaths that occur annually in the United States (Myerburg et al., 1998). Improvement in risk-stratification techniques and strategies to consider costs and benefits in the general population is driving the evolution of AICD use in the community.

Torsade de Pointes

Torsade de pointes is a syndrome consisting of polymorphic ventricular tachycardia with QT prolongation. Polymorphic ventricular tachycardia without QT prolongation most commonly occurs in the setting of acute myocardial ischemia. Although polymorphic ventricular tachycardia is often faster than sustained monomorphic ventricular tachycardia and thus can lead to hemodynamic instability, many episodes of polymorphic ventricular tachycardia terminate spontaneously. Initial management for polymorphic ventricular tachycardia without QT prolongation is similar to that for monomorphic ventricular tachycardia, with defibrillation and antiarrhythmic drugs (Grogan & Scheinman, 1993).

Torsade de pointes can occur in the absence of structural heart disease. Acquired QT prolongation is most often caused by drugs, including type I and type III antiarrhythmic agents, tricyclic antidepressants, phenothiazines, nonsedating antihistamines, erythromycin, pentamidine, and azole antifungal agents. QT prolongation may also be caused by electrolyte abnormalities, especially hypomagnesemia, and exacerbated by other conditions such as hypothyroidism, cerebrovascular accident, and liquid protein diets (Napolitano et al., 1994).

Torsade de pointes is triggered by early afterdepolarizations, oscillations in the membrane potential that occur during prolonged repolarization, usually in the setting of an accumulation of intracel-

lular positive ions. This abnormality can occur from malfunctioning ion channels, electrolyte disruptions, or by medications, and may be exacerbated by increased sympathetic activity. The early after depolarizations depolarize nearby cell membranes, which can result in action potentials, initiating polymorphic ventricular tachycardia.

The ECG of torsade de pointes will show a beat-to-beat change in the QRS axis, irregular RR intervals, and a heart rate ranging from 160 to 250 bpm. A pause may be seen before the onset of torsade. Ventricular bigeminy in a patient with a long QT interval may be a sign of impending torsade. On the resting ECG, the QT interval varies inversely with the heart rate and therefore must be corrected, usually using Bazett's formula, in which the corrected QT interval (QTc) is the QT interval divided by the square root of the RR interval in milliseconds. A QTc of more than 0.44 seconds in men and more than 0.45 seconds in women is considered prolonged.

Empiric magnesium (2 g intravenously over 1 to 2 minutes) should be given to all patients with suspected torsade de pointes because the risk is low and the potential benefits high. Because the length of the QT interval is affected by the RR interval, use of isoproterenol or temporary pacing in patients with acquired QT prolongation and torsade de pointes to increase the heart rate can be effective (Roden, 1993). Nonsynchronized electrical defibrillation may be required in hemodynamically unstable patients.

Long QT Syndrome

Congenital long QT (LQT) syndrome is a disorder of ventricular repolarization characterized by a prolonged QT interval. This prolongation of the QT interval predisposes the patient to torsade de pointes, ventricular fibrillation and sudden cardiac death. Forms of congenital LQT syndrome include Jervell and Lange-Nielsen syndrome, which is associated with sensorineural deafness, and Romano-Ward syndrome. Genes responsible for LQT syndrome have been identified and the syndrome classified into subtypes according to mutation. Of the two most common mutations, LQT type 1 is associated with mutations in KVLQT1, an outward-rectifying cardiac potassium channel protein, LQT type 2 with mutations in the human ether-related-a-go-go (*HERG*) gene, another component of the outward-rectifying potassium channel, and LQT type 3 with mutations in the cardiac sodium channel gene *SCN5A*. This is

important because these three subtypes have different arrhythmic triggers and respond differently to medications. LQT syndrome is perhaps the best example of the use of genotyping to guide prognosis and therapy in current cardiological practice.

The signs and symptoms of congenital LQT syndrome occur during childhood or adolescence. Syncope or cardiac arrest during physical exertion or emotional stress may be the first presenting symptom. Arrhythmic events in patients with LQT1 are most often related to exercise, and also with swimming. Events triggered by auditory stimuli, such as alarm clocks and telephones, are most typically seen in patients with LQT2. Patients with LQT3 are at highest risk of events when at rest or asleep. The clinical course of LQT syndrome is also influenced by genotype; patients with LQT1 tend to have the earliest events and a worse prognosis, and those with LQT3 have a later onset and a lower overall event rate. There is also a difference in clinical course with different mutations within one subtype.

The mainstay of pharmacological therapy for congenital LQT syndrome is β -blockade, titrated to blunt the maximum heart rate achieved by exertion. Competitive sports should be avoided. The efficacy of β -blockers varies with genotype; they are most effective in patients with LQT1, and least effective in patients with LQT3. Left cardiac sympathetic denervation is occasionally performed to prevent cardiac events. Cardiac pacing has been employed in patients who remain symptomatic despite medical therapy, and may be especially useful in patients with LQT3. AICD implantation is recommended in patients who have recurrent syncope, sustained ventricular arrhythmias, or sudden cardiac death despite drug therapy (Antzelevitch et al., 2005; Gregoratos et al., 1998).

Arrhythmogenic Right Ventricular Dysplasia

Arrhythmogenic right ventricular dysplasia (ARVD) is a myocardial disorder in which there is replacement of the right ventricle myocardium with fatty or fibrofatty tissue, with the potential for a reentrant ventricular tachycardia and sudden death. ARVD occurs in families, with both an autosomal dominant and autosomal recessive form. A familial form of ARVD accompanied by hyperkeratosis and woolly hair with autosomal recessive inheritance was identified on a Greek island and termed Naxos disease.

The clinical manifestations include palpitations, dizziness, syncope, right-sided heart failure, sustained or nonsustained monomorphic ventricular tachycardia and sudden cardiac death. The ECG is characteristic, includes a prolonged QRS complex with a right bundle branch pattern, ϵ wave (electric potentials after the end of the QRS complex) and T-wave inversions in leads V_1 to V_3 . Diagnostic testing includes echocardiography, signal-averaged ECG, and magnetic resonance imaging, which is the best method to demonstrate fatty infiltration of the right ventricular (RV) myocardium. Signal-averaged ECG may be used to screen family members.

Both ventricular tachycardia and sudden death can be exercise-induced, possibly due to RV stress and catecholamine stimulation, and so patients with ARVD should not participate in competitive sports. Therapy should be aimed at suppression of arrhythmias. Sotalol is the most effective antiarrhythmic medication for suppressing ventricular arrhythmias in ARVD. Amiodarone is the second choice. Implantable defibrillators are indicated (class I) for symptomatic patients and survivors of sudden cardiac death, and may be considered (class Iia) for secondary prevention and a class IIa for primary prevention of ventricular tachycardia in ARVD (Priori et al., 2001). Ablation of arrhythmic foci has been undertaken, but ARVD tends to progress, and so this therapy is usually reserved for patients with non-life-threatening but symptomatic tachyarrhythmias who are intolerant of antiarrhythmic drugs.

Brugada Syndrome

Brugada syndrome is a rare genetic disease that is characterized by ST elevation unrelated to electrolyte disorders or coronary ischemia. Brugada syndrome can cause sudden cardiac death from ventricular fibrillation in individuals with structurally normal hearts. The ECG findings are distinctive, and include a pseudo-right bundle branch block pattern with ST elevation in leads V_1 through V_3 . Cases of Brugada syndrome have now been linked with mutations in the cardiac sodium channel gene *SCN5A* (Chen et al., 1998). There is some suggestion that Brugada syndrome may be an early manifestation of arrhythmogenic RV dysplasia, but this is uncertain.

The diagnosis of Brugada syndrome relies on the ECG findings and the clinical presentation. The diagnosis of Brugada syndrome

should be considered if the patient has coved type ST segment elevation in more than one precordial lead and one of the following: documented ventricular fibrillation, self-terminating polymorphic ventricular tachycardia, a family history of sudden cardiac death at age less than 45 years old, coved ST segment elevation in family members, electrophysiological inducibility, syncope, and nocturnal agonal respiration (Wilde et al., 2002). A patient with ECG findings without clinical manifestations is defined as having Brugada pattern (Wilde et al., 2002).

There are no well-established pharmacological therapies. β -Blockers and amiodarone have not been shown to be beneficial. There is some suggestion that quinidine may be useful (Belhassen et al., 2004).

Implantation of an AICD is the only currently proven therapy to prevent sudden death, and is recommended in patients with syncope, symptomatic ventricular tachycardia, or a prior history of aborted sudden cardiac death (Gregoratos et al., 1998; Priori et al., 2001). What to do with asymptomatic patients is less certain. Stratification by electrophysiological testing, with AICD implantation in patients with inducible ventricular tachycardia, has been advocated (Antzelevitch et al., 2005).

Bradycardias

SINUS NODE DYSFUNCTION

Bradycardias associated with sinus node dysfunction include sinus bradycardia, sinus pause, SA block, and sinus arrest. These disturbances often result from increased vagal tone (Atlee, 1997). If bradycardia is transient and not associated with hemodynamic compromise, no therapy is necessary. If bradycardia is sustained or compromises end-organ perfusion, therapy with antimuscarinic agents, such as atropine, or β -agonists such as ephedrine may be initiated. Transcutaneous or transvenous pacing may be necessary in some cases.

Patients with a combination of bradycardia with paroxysmal atrial tachycardias owing to pre-existing conduction system disease can be challenging to manage pharmacologically. In these cases, insertion of a temporary pacemaker may allow the administration of rate-lowering agents.

Heart Block

The most common cause of acquired chronic AV heart block is fibrosis of the conducting system. Although pre-existing conduction system disease is a risk factor for the development of complete heart block, no single laboratory or clinical variable identifies patients at risk for progression to high-degree AV block (Gregoratos et al., 1998). In first-degree AV block there is prolongation of conduction time of the atrial impulses to the ventricles, with a PR interval greater than 200 ms. In second-degree AV block, conducted atrial beats are interspersed with nonconducted beats. Second-degree AV block is divided into Mobitz type I (Wenckebach) and Mobitz type II block. In Mobitz I block, the PR interval lengthens progressively until the P-wave fails to conduct. In most cases, the block occurs at the AV node. Mobitz I block can occur in healthy individuals, the elderly, and in patients with underlying heart disease. In Mobitz type II AV block the PR interval remains constant until a P-wave fails to conduct. Mobitz II block occurs below the AV node, and thus is more dangerous since it is much more likely to progress to complete heart block. In third-degree AV block, none of the atrial impulses are conducted to the ventricles. The escape rhythm, whether junctional or ventricular, is generally regular.

Patients with AV block may be asymptomatic, but may experience dizziness or syncope as a consequence of decreased cardiac output. AV block is most commonly caused by AV nodal conduction disease, but AV nodal-blocking agents need to be ruled out as causative agents. Any medications that affect conduction through the AV node should be decreased or discontinued if possible.

Recommendations for pacemaker implantation differ a bit among societies, but in general are predicated on symptoms and the potential for progression to higher degrees of heart block. A pacemaker is generally not recommended in most cases of first-degree AV block, although it may be considered in patients with marked PR prolongation (>300 ms) and LV dysfunction with heart failure symptoms (Gregoratos et al., 1998). A second- or third-degree block and either symptomatic bradycardia or congestive heart failure is a class I indication (general agreement that a treatment is beneficial) for insertion of a pacemaker (Gregoratos et al., 1998). The ACC/AHA/NASPE have given permanent pacing for asymptomatic patients with Mobitz type II AV block a class IIa recommendation (conflict-

Table 2
Recommendations for Permanent Pacing
After the Acute Phase of Myocardial Infarction

<i>Class I</i>	<ul style="list-style-type: none"> • Persistent second-degree AV block in the His-Purkinje system with bilateral bundle branch block or complete heart block after acute myocardial infarction. • Transient advanced (second- or third-degree) infranodal AV block and associated bundle branch block. If the site of block is uncertain, an electrophysiological study may be necessary • Persistent and symptomatic second- or third-degree AV block.
<i>Class IIb</i>	<ul style="list-style-type: none"> • Persistent second- or third-degree AV block at the AV node level.
<i>Class III</i>	<ul style="list-style-type: none"> • Transient AV block in the absence of intraventricular conduction defects • Transient AV block in the presence of isolated left anterior fascicular block. • Acquired left anterior fascicular block in the absence of AV block. • Persistent first-degree AV block in the presence of bundle branch block that is old or age indeterminate.

Class I: evidence and/or general agreement that a treatment is beneficial; Class II: conflicting evidence, efficacy less well established; Class III: evidence and/or general agreement that a treatment is not useful and in some cases maybe harmful. (Adapted from Gregoratos et al., 2002.)

ing evidence, but weight of evidence favors usefulness) (Gregoratos et al., 1998). Permanent pacing was given a class I indication for all patients with third-degree or advanced heart block and either symptomatic bradycardia, pauses greater than 3 seconds, or escape rates less than 40 bpm. A class IIa recommendation for permanent pacing was given for patients with asymptomatic third-degree AV block (Gregoratos et al., 1998).

Pacemaker implantation is also indicated in patients who have bradycardia–tachycardia (“sick sinus”) syndrome, and other arrhythmias or medical conditions that require drugs that result in symptomatic bradycardia (Gregoratos et al., 1998). Pacing may also be considered for patients with an inadequate chronotropic response to exercise.

Table 3
Recommendations for Temporary Transvenous
Pacing After an Acute Myocardial Infarction

<i>Class I</i>	<ul style="list-style-type: none"> • Asystole • Symptomatic bradycardia • Bilateral bundle branch block (alternating BBB or RBBB with alternating LAFB/LPFB, any age) • New or indeterminate-age bifascicular block (RBBB with LAFB or LPFB, or LBBB) with first-degree AV block • Mobitz type II second-degree AV block
<i>Class IIa</i>	<ul style="list-style-type: none"> • RBBB and LAFB or LPFB (new or indeterminate). • RBBB with first-degree AV block • LBBB, new or indeterminate. • Incessant VT, for atrial or ventricular overdrive pacing. • Recurrent sinus pauses (greater than 3 seconds) not responsive to atropine.
<i>Class IIb</i>	<ul style="list-style-type: none"> • Bifascicular block of indeterminate age. • New or age-indeterminate isolated RBBB.
<i>Class III</i>	<ul style="list-style-type: none"> • First-degree heart block. • Type I second-degree AV block with normal hemodynamics. • Accelerated idioventricular rhythm. • BBB or fascicular block known to exist before acute MI

RBBB, right bundle branch block; LBBB, left bundle branch block; LAFB, left anterior fascicular block; LPFB, left posterior fascicular block; AMI, acute myocardial infarction. Class I: evidence and/or general agreement that a treatment is beneficial; Class II: conflicting evidence; Class IIa: weight of evidence is in favor of efficacy; Class IIb: weight of evidence is less well established; Class III: evidence and/or general agreement that a treatment is not useful and maybe harmful. (Adapted from Ryan et al., 1999.)

Conduction abnormalities are a common complication of acute MIs. These can be transient or permanent. Conduction abnormalities associated with an acute inferior MI usually result from AV nodal ischemia, are transient, and carry a low mortality rate. Conduction abnormalities in association with an acute anterior MI, however, represent extensive necrosis of the infranodal conduction system and the myocardium, and are associated with high in-hospital mortality (Hindman et al., 1978). The ACC/AHA/NASPE recommended guidelines for permanent and temporary implantation of pacemakers in patients with an acute MI and shown in Tables 2 and 3.

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