Arrhythmias in Adult Congenital Heart Disease

Historically, many congenital cardiac defects resulted in death in infancy or early childhood, with few individuals living into young adulthood. Through advances in modern cardiovascular care, there are now almost 1 million adults with congenital heart disease (CHD) living in the United States and, interestingly, more adults than children. As a consequence of these operative repairs and the added longevity, arrhythmias are increasingly common.

Mayo Clinic in Rochester is one of the largest adult CHD centers in the world and manages all types of CHD using a multidisciplinary team approach of cardiologists, cardiac surgeons, and electrophysiologists. Many key insights into these complex disorders have developed out of research from this group, and it is seen as a leader in disease-specific syndromes such as Ebstein’s anomaly and tetralogy of Fallot.

“Arrhythmias in this group are a major cause of hospital admission and morbidity in patients with CHD and also are the most common reason for late mortality,” says Christopher J. McLeod, MB, ChB, PhD, congenital electrophysiologist at Mayo Clinic in Rochester. “Moreover, some of the rhythm abnormalities such as the atrial arrhythmias, which are often benign in the general population, are poorly tolerated and are associated with a substantial increase in mortality in this group.”

Background

Some element of CHD is present in about 1% of live births. Of these, about half have "milder" forms of disease, such as atrial septal defects (ASD) and ventricular septal defects (VSD), while the remainder have more complex physiology, the most common of these being tetralogy of Fallot. Symptomatic bradyarrhythmias can cause considerable morbidity and mortality. Pacemaker implantation is required in about 3% to 4% of patients with Ebstein’s anomaly or ASD closure, but in more than 80% of patients who have complete transposition of the great arteries who had a Mustard or Senning operation or patients with congenitally-corrected transposition of the great arteries.

Atrial tachyarrhythmias afflict at least a quarter of all individuals with CHD during their lifetimes. About half of patients with ASD repair after age 25 and nearly one-third of patients with tetralogy of Fallot develop atrial tachyarrhythmias. Ventricular arrhythmia and sudden cardiac death also are inextricably interwoven in this group of patients, as they occur in about a quarter of patients. This incidence is 25 to 100 times higher than in an age-matched control population, and risk stratification for implantable cardioverter-defibrillator (ICD) implantation for primary prevention remains a major hurdle.

The mechanism behind these arrhythmias can be inherent to the congenital anomaly, such as abnormalities in atioventricular (AV) nodal function in the AV septal defects. However, bradycardias are most commonly seen as a consequence of the operative repair, either in the early postoperative period or later due to fibrosis developing in the context of prior operative scars. Tachycard-
Atrial tachyarrhythmias are also a frequent cause of morbidity and are seen in around a third of patients; this is typically an intra-atrial reentrant tachycardia that is amenable to ablation and less so to medications. Antiarrhythmic medications are useful adjuncts in addressing these rhythm abnormalities in symptomatic patients, but they are limited by long-term toxicity and poor efficacy.

**Ebstein’s Anomaly**

Ebstein’s anomaly encompasses a wide spectrum of maldevelopment of the tricuspid valve, massive right atrial dilatation, and underdeveloped right ventricular function. Accessory pathways are present in at least one-fifth of patients with Ebstein’s anomaly, almost always right-sided (or concordant with the side of Ebstein valve in case of transposition) and not infrequently multiple. Catheter ablation is highly effective in eliminating these accessory pathways and should be considered as first-line therapy.

Atrial arrhythmias are especially common in this group and, importantly, can conduct rapidly to the ventricle via the accessory pathway, resulting in hemodynamic deterioration, syncope, and even death. In the setting of atriplasty, maze procedures, and prosthetic valves, these atrial rhythm abnormalities can be complex and frequently require ablation and/or antiarrhythmic drug therapy.

**Atrial Septal Defects**

ASD is one of the most common congenital cardiac anomalies and is associated with a high incidence of atrial arrhythmias that increase in frequency as the patient ages. The later in life the ASD is repaired, the more likely atrial arrhythmias are to develop. Closure does not mitigate the development of arrhythmias, and with the advent of percutaneous ASD closure devices, can in fact complicate management. In addition, significant thromboembolic complications have been observed in patients who had ASD closure performed in the third decade or older, affecting up to a quarter of these patients.

Therefore, anticoagulation should be mandatory if atrial arrhythmias develop and should be actively sought using ambulatory monitoring. Intra-atrial reentrant tachycardia circuits around a patch or suture line frequently underlie the abnormality, and ablative therapy is often first-line treatment (Figure).

**Prior Maze Procedure**

Modified Cox-maze operations are a common, safe, and highly effective surgical method of restoring sinus rhythm in patients with CHD and atrial fibrillation/flutter. These interventions are most commonly performed at the time of CHD operations and can be unilateral or bilateral depending on the underlying congenital lesion. Unfortunately, patients with prior maze procedures can develop breakthrough atrial tachyarrhythmias at points of incomplete atrial block. This development is substantially less common with traditional “cut-and-sew” maze procedures than with open surgical radiofrequency or cryotherapy approaches.

The maze procedure is not free of complications; the extensive transmural lesions not only potentially interfere with sinus and intra-atrial conduction but also likely disrupt atrial innervation. Sinus node dysfunction, atrial bradyarrhythmias and tachyarrhythmias, and chronotropic incompetence are not uncommon sequelae, and pacemaker implantation is frequently necessary. New postmaze atrial tachyarrhythmias can develop around and through the incomplete maze lesions, and ablation of intra-atrial reentrant tachycardia in this setting is frequently undertaken. Antiarrhythmic drug therapy is also relied on in this context, and atrial antitachycardia pacemakers can be of added utility in this particular type of atrial arrhythmia.
Management
It is critical for clinicians to recognize that patients with congenital defects (and repairs) have not been included in any of the large atrial fibrillation trials such as the Atrial Fibrillation Follow-Up Investigation of Rhythm Management (AFFIRM) and How to Treat Chronic Atrial Fibrillation (HOT-CAFÉ) rate-versus-rhythm studies, any of the anticoagulation trials evaluating risk stratification schemes such as CHADS2, or efficacy trials involving novel anticoagulation agents. Each patient therefore needs to be carefully evaluated and treated on an individual basis at a center specialized in adult CHD.

"Importantly, for any atrial tachyarrhythmia that is associated with hemodynamic instability, synchronized direct current cardioversion should be utilized without delay," says Dr McLeod.

Antiarrhythmic drugs remain a cornerstone in the management of atrial arrhythmias in CHD patients; however, most antiarrhythmic drugs should not be routinely used in this patient group because of the risks of proarrhythmia. Important differences in management are highlighted as follows:

Ablation
Radiofrequency catheter ablation is now utilized early in the course of many adult patients with atrial tachyarrhythmias, particularly for atrial arrhythmias. Radiofrequency catheter ablation in these patients can be challenging and should be referred to experienced centers. Although early success rates are excellent even in the most complex defects, long-term recurrence rates remain suboptimal, especially when multiple circuits coexist and atrial scars are abundant. The reentrant circuit can often be modified sufficiently to reduce symptomatic recurrence and improve antiarrhythmic drug therapy or pacing efficacy.

Device therapy
Similar to acquired heart disease, symptomatic bradyarrhythmias require permanent pacing, but knowledge of intracardiac and vena caval anatomy is critical. To avoid thromboembolic complications, epicardial pacemaker placement is mandatory if a residual intracardiac shunt exists. Coronary sinus lead placement can also be utilized in selective cases where the tricuspid valve cannot be crossed, and atrial antitachycardia devices are typically reserved for patients who also present with bradycardia. ICD implantation is frequently appropriate, and the newer subcutaneous ICD systems provide a useful alternative in selected groups.

Anticoagulation therapy
Anticoagulation therapy should be considered in CHD patients as soon as an atrial rhythm disturbance is identified. Patients with Fontan circulation or reduced ventricular function have low flow states in the heart and are at high risk of thrombus formation within the atria. Patients with repaired ASD also appear to be at considerable risk of thromboembolic complications in the setting of atrial arrhythmias, accounting for about one-fifth of late deaths in 1 series.

"The use of conventional thromboembolic risk-assessment scores, such as CHADS2, has not been evaluated in these patient groups and likely is inappropriate," says Dr McLeod. The newer oral anticoagulant agents such as dabigatran, rivaroxaban, and apixaban also have not been specifically studied in CHD patients.

Summary
Atrial and ventricular arrhythmias are a major cause of late morbidity and mortality in this group of patients and should be managed at a specialized center. The Center for Congenital Heart Disease and the Heart Rhythm Clinic at Mayo Clinic in Rochester continue to be at the forefront in the multidisciplinary management of these complex patients who typically require multimodal strategies involving antiarrhythmic drugs, detailed electrophysiological studies, radiofrequency catheter ablation, and device therapy.

IN THE NEWS

New Cell Therapy Trial for Ischemic Cardiomyopathy
Do you have a patient with ischemic cardiomyopathy, heart failure symptoms despite optimal medical therapy, and an ejection fraction less than 35%? Does your patient already have an implantable cardioverter-defibrillator (ICD) or cardiac resynchronization therapy-implantable cardioverter-defibrillator (CRT-ICD) device?

If you answered yes to these questions, your patient may be a candidate for a new cell-based therapy trial at Mayo Clinic in Rochester. In this trial, patients will donate a sample of their own bone marrow for cell processing. The processed cells are then injected into damaged areas of the heart in the cardiac catheterization laboratory. This trial is blinded and randomized, so some patients will initially have a sham injection. After a 1-year follow-up, patients in the control group will have the opportunity to receive the cell therapy treatment as well.

Principal investigators are Guy S. Reeder, MD, and Alfredo L. Clavel, MD, cardiologists at Mayo Clinic in Rochester.

Inclusion criteria
• Ages 30-86
• Ejection fraction < 35%
• ICD already in place
• NYHF Class III-IV
• All options for usual evidence-based heart failure treatments have been given

Exclusion criteria
• Severe valvular disease, including aortic stenosis and insufficiency or aortic valve prosthesis
• Current or planned left ventricular assist device (LVAD) or heart transplant (status 1A or 1B)
• Myocardial infarction, cerebrovascular accident, or cardiac surgery in the last 3 months
• Active ETOH or drug abuse, Hgb < 9, blood clotting disorder, hepatis B or C, or HIV
• Chronic kidney disease on dialysis

Contact Beth A. Kaping, RN, at 507-255-7962 or Cindy M. Woltman, RN, at 507-266-4095 for more information.
Pregnancy Complicated by Maternal Congenital Cardiac Disease

Maternal cardiac disease complicating a pregnancy occurs in approximately 1% to 3% of pregnancies. The etiology of the cardiac disease includes congenital defects, rheumatic heart disease, cardiomyopathy, and ischemic disease. The prevalence of these etiologies varies by region, with rheumatic heart disease still the most common concern in the developing world. However, in the United States, declining cases of rheumatic heart disease and improved survival of patients with congenital heart disease have resulted in congenital defects being the most common cause of maternal heart disease affecting pregnancy.

The cardiovascular changes during pregnancy superimposed on the altered physiology of many congenital defects can lead to maternal and fetal complications, and require expert management and evaluation during the antepartum, peripartum, and postpartum periods. A multidisciplinary team approach is optimal, with participation from congenital cardiology, cardiac surgery, maternal and fetal medicine, anesthesiology, and neonatology.

The hemodynamic changes during pregnancy are significant and begin early in gestation. Heart rate, stroke volume, afterload, preload, and contractility are all affected, with heart rate increases occurring as early as 2 weeks after conception. Increases in heart rate, stroke volume, preload, and contractility combined with a drop in afterload result in increased cardiac output throughout pregnancy. The most significant increase in cardiac output occurs during the first 2 trimesters.

Cardiac structure is also altered by pregnancy, with increased ventricular wall thickness and ventricular mass noted. Overall, blood volume increases by approximately 40% and cardiac output by about 45% during gestation. Labor and delivery requires additional alterations in cardiac physiology, including a further increase in cardiac output by 30% during contractions.

Maternal and fetal outcomes of a pregnancy complicated by maternal cardiac disease depend on the interaction of the physiology of the specific cardiac lesion with the altered cardiac physiology of pregnancy. While many women with cardiac disease can complete a pregnancy successfully, there are cardiac conditions that pose a high risk of maternal mortality, so pregnancy is contraindicated for these women. These conditions include pulmonary hypertension (pulmonary artery pressure > 75% systemic), ventricular dysfunction with NYHA Class III-IV heart failure symptoms, and Marfan syndrome with aortic enlargement > 40 mm. Many cardiac conditions, including those with outflow obstruction, cause increased risk to the mother and fetus but are not absolutely contraindicated. Therefore, a risk model has been developed by Canadian investigators (Siu et al. Circulation. 2001;104:515-521) to appropriately advise patients regarding risk of cardiac complication during pregnancy (Table and Figure).

Ideally, mothers should seek consultation prior to pregnancy to best understand their cardiac risk and develop a plan for care during gestation and delivery. Cardiac care during the pregnancy may include starting or adjusting cardiac medications, utilizing catheter-based procedures, or even undergoing cardiac surgery. A review of patients undergoing cardiopulmonary bypass during pregnancy at Mayo Clinic demonstrated a fetal loss rate of 21%. Fetal loss was associated with emergency cardiac surgery, early gestational age, and maternal comorbidities.

The risk of pregnancy in patients with complex anatomy and single-ventricle physiology is not easily assessed, but successful pregnancies are reported in this cohort of patients with the most severe congenital heart diseases.

The Fontan procedure, a surgical intervention that directs caval blood flow to the pulmonary arteries, is used to palliate patients with single-ventricle physiology. The cardiac output after Fontan is determined by the central venous pressure (CVP), the left atrial pressure (LAP), and the pulmonary vascular resistance (PVR) (cardiac output = [CVP-LAP]/PVR).

Patients with Fontan physiology are preload...
dependent, and it can be difficult to significantly increase cardiac output. These patients have an increased incidence of atrial arrhythmias and intra-cardiac thrombi, impacting their ability to complete a pregnancy without complications. A recent multicenter retrospective study of 71 pregnancies in patients after a Fontan demonstrated a 73% live birth rate, with a high rate of preterm delivery (average gestational age of 34 weeks). Maternal cardiac complications occurred in 37% and obstetrical complications in 52% of these pregnancies. There was no maternal mortality during pregnancy, but it was unclear from these data if long-term survival is affected.

There is an increased risk of fetal congenital cardiac disease in the offspring of a parent with a congenital heart defect. Therefore, pregnancy management should include evaluation of the fetus for cardiac abnormalities. Fetal echocardiography is an excellent tool that can be utilized optimally at 18 to 22 weeks gestation for delineation of fetal cardiac anatomy.

### Table

**Predictors of Primary Cardiac Events During Pregnancy**

1. Prior cardiac event (heart failure, TIA, or stroke) or arrhythmia
2. NYHA functional class > II or cyanosis
3. Left heart obstruction (mitral valve area < 2 cm², aortic valve area < 1.5 cm², or peak left ventricular outflow tract gradient > 30 mm Hg by echocardiography)
4. Systemic ventricular dysfunction (ejection fraction < 40%)

**Source:** Modified from Siu SC, et al. Prospective multicenter study of pregnancy outcomes in women with heart disease. Circulation. 2001;104:515-521. (Table 4 is presented as a figure.)

### Case Study

**Presentation**

At Mayo Clinic, a 32-year-old woman presented at 11 weeks gestation for a second opinion on the risk of continued pregnancy. A murmur had been heard 2 weeks prior to the consultation during an office visit for an upper respiratory tract infection. Further investigation with echocardiography demonstrated severe aortic valve stenosis with a bicuspid aortic valve. The ascending aortic dimension was normal, as was the left ventricular systolic function. The patient was active and asymptomatic, having delivered a healthy term infant 15 months prior. Termination of the current pregnancy had been advised at another institution.

Using the risk model, the patient was felt to have approximately a 30% risk of cardiac complication during pregnancy. It was emphasized to the patient that the risk of death was low. The patient elected to continue the pregnancy with close observation. The patient was seen regularly by maternal-fetal medicine and congenital cardiology. At 20 weeks gestation, a fetal echocardiogram demonstrated fetal situs inversus without evidence of other structural heart disease. The patient was seen in consultation with pediatric cardiology and neonatology. The pregnancy progressed without symptoms. In the third trimester, the patient met with anesthesia and a delivery plan was developed.

**Follow-Up**

The patient relocated to Rochester, Minnesota, at 37 weeks gestation to be near the delivery medical center. At 39 weeks gestation, spontaneous labor occurred and a healthy infant was delivered.

The case demonstrates the importance of cardiac consultation with a specialist in the care of pregnancy complicated by maternal cardiac disease to appropriately assess risk and develop a multidisciplinary approach to improve the odds of successful maternal and fetal outcomes.
Mayo Clinic Hospital in Phoenix, Arizona, was named to the Truven Health 50 Top Cardiovascular Hospitals list for the eighth year in a row.

Bernard J. Gersh, MB, ChB, DPhil, member of the Division of Cardiovascular Diseases at Mayo Clinic in Rochester, was named 1 of 4 legends of modern cardiology at the 2013 European Society of Cardiology annual meeting in Amsterdam, Netherlands.

Robert E. Shaddy, MD, chief of the Division of Cardiology at the Children’s Hospital of Philadelphia, was the eighth annual David J. Driscoll, MD, Visiting Lecturer. Dr Shaddy (right) is pictured with Dr Driscoll, former chair of the Division of Pediatric Cardiology at Mayo Clinic in Rochester.

Craig R. Smith, MD, chairman of the Department of Surgery at Columbia University College of Physicians and Surgeons in New York City, was the 24th annual John W. Kirklin Visiting Professor in Cardiac Surgery. Dr Smith (right) is pictured with Joseph A. Dearani, MD, chair of the Division of Cardiovascular Surgery at Mayo Clinic in Rochester.

William D. Edwards, MD, cardiac pathologist, and David J. Driscoll, MD, pediatric cardiologist, were named 2013 Distinguished Educators at Mayo Clinic in Rochester.

The Mayo Clinic Cardiovascular Self-Study Tutorial Series was launched in June 2013 as part of an ongoing initiative by the Mayo Clinic Division of Cardiovascular Diseases to provide the finest educational tools for continuing medical education. The expanded self-study series now offers selections in a variety of cardiac subspecialties and provides updates on the latest advances and clinical practice.

Topics include adult and congenital echocardiography, multimodality imaging, electrocardiography, electrophysiology, and circulatory failure. Tutorials featuring topics in peripheral vascular disease, nuclear imaging, structural heart disease, and ischemic heart disease are upcoming. Lectures in the series range in length from 30 minutes to 3 hours. Tutorials qualify for AMA PRA Category 1 Credits.

You can view the tutorials and obtain credit at https://cardiovascular.education-registration.com/selfstudy. A brief overview is available on YouTube at https://www.youtube.com/watch?v=2SHAxcg9cNU.

In 2014, the Cardiovascular Self-Study Tutorial Series will be exhibiting at 3 national meetings (American College of Cardiology, American Society of Echocardiography, and American Heart Association), 4 regional CME meetings, and all Cardiovascular Board Review meetings held in Rochester, Minnesota.

Contact
Email: CVselfstudy@mayo.edu
Phone: 800-283-6296 or 507-266-6645
Fredrick A. Willius, MD, arrived at Mayo Clinic in 1915 to begin his postgraduate medical training after graduating from the University of Minnesota Medical School. Mayo Clinic had received its first electrocardiograph (ECG) machine the year before; the instrument, manufactured by Cambridge Scientific Instrument Company in England, was large, expensive, complicated, and difficult to maintain. Nevertheless, Henry S. Plummer, MD, a prominent internist at Mayo Clinic, saw the clinical potential of the ECG and had ordered a machine. When it arrived, it was installed in the newly completed Mayo Clinic building (located where the Siebens Building now stands).

By the time Dr Willius began working in the ECG laboratory in 1916, more than 1200 outpatient ECGs had already been performed at Mayo Clinic. The following year, he was placed in charge of the ECG laboratory. In other times, a more senior physician might have been given that position, but these were not ordinary times. Many of the Mayo Clinic staff were serving in the military during World War I; others were unavailable due to the evolving influenza pandemic. Dr Willius trained a team of technicians to perform ECGs, expanding the Mayo Clinic team staffing model that exists to this day.

The development of the ECG was a critical step in the evolution of cardiology as a specialty and of Dr Willius’ career as a cardiologist. Initially, it was used to study heart rhythms, but Dr Willius was one of the first to recognize the utility of the ECG in characterizing other types of heart disease in both research and clinical settings. He was particularly interested in T wave changes observed in tracings obtained during episodes of chest pain. He published his first book, *Clinical Electrocardiography*, in 1922, and in it described not only various arrhythmias but also ECG findings in other cardiac and pulmonary diseases.

In 1923, the Mayo Clinic Board of Governors established a separate section of cardiology, and Dr Willius was named the chair on the recommendation of Dr Plummer. A second ECG machine was placed in the Kahler Hospital (now the Kahler Grand Hotel). In his first annual report, Dr Willius noted that he and his assistant, Arlie Barnes, MD, had supervised ECGs on 4369 outpatients and 1269 inpatients and provided cardiac evaluations on 4695 patients. Dr Barnes would become the second cardiologist at Mayo Clinic.

Dr Willius hosted an organizational meeting of the Minnesota Cardiologic Club in 1924. It was an informal group of physicians with a passionate interest in the heart and circulatory system. The name was changed to the Minnesota Heart Association in 1925, when it became affiliated with the American Heart Association. As the organization’s first president, Dr Willius argued that the group not only study heart disease but also expand its mandate to the prevention of heart disease. He coauthored 1 of 9 papers presented at the inaugural meeting of the American Heart Association in Atlantic City, New Jersey, in 1925.

Dr Willius recognized the importance of professional communication and collaboration in the development of a premier academic cardiology program. To that end, prominent American and European physicians and scientists were invited to Rochester, Minnesota, to speak beginning in 1923, including Karel Wenckebach of Vienna, Austria; Emanuel Libman of New York City, New York; and Ludwig Aschoff of Freiburg, Germany. Dutch physiologist Willem Einthoven came to Mayo Clinic to speak less than 2 weeks after he learned that he had won a Nobel Prize for the invention of the electrocardiogram.

Dr Willius maintained an active speaking program throughout the country. He speculated that hypertension, high-fat diets, sedentary lifestyles, and smoking likely played a role in the development of heart disease long before clinical trials had confirmed them as risk factors. He also noted that heart disease was increasing in women and ventured that it was a result of women increasingly adopting predisposing lifestyles and habits.

Dr Willius retired from Mayo Clinic in 1953 and died in 1972. He lived to see the development of the heart-lung bypass machine and the opportunities it afforded to bypass diseased coronary arteries, replace heart valves, and repair congenital heart defects. Most importantly, he lived to see the division he created at Mayo Clinic evolve into a world-class cardiac center.
Continuing Medical Education, Mayo Clinic
For additional information:
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Mayo Echocardiography Review Course for Boards and Recertification
Apr 26-29, 2014
Rochester, MN

Echo Fiesta: An In-Depth Review of Adult Echocardiography for Sonographers and Physicians
May 1-4, 2014
San Antonio, TX

Basic to Advanced Echocardiography: From the Riverfront of Savannah
May 14-17, 2014
Savannah, GA

Cardiac Rhythm Device Summit: Implantation, Management, and Follow-up
Jun 13-15, 2014
Chicago, IL

Jul 20-24, 2014
Vail, CO

Cardiology Update 2014: The Heart of the Matter
Jul 31-Aug 3, 2014
Sedona, AZ

Success With Heart Failure: Strategies for the Evaluation and Treatment of Heart Failure in Clinical Practice
Aug 11-13, 2014
Dana Point, CA

19th Annual Mayo Cardiovascular Review Course for Cardiology Boards and Recertification With Pre-Course Echo Focus Session (Aug 15)
Aug 15-20, 2014
Rochester, MN

Pediatric Cardiology 2014 Review Course
Aug 17-22, 2014
Dana Point, CA

Electrophysiology Review for Boards and Recertification
Sep 5-8, 2014
Rochester, MN

Challenges in Clinical Cardiology: A Case-Based Update
Sep 12-14, 2014, Chicago, IL

Echocardiography for the Sonographer: Practical Review of Valvular Heart Disease
Sep 20-21, 2014, St. Louis, MO

11th Annual Mayo Clinic Interventional Cardiology Board Review
Sep 26-28, 2014
Rochester, MN

Advanced Cardiovascular Imaging 2014: Interactive and Case-Based Review
Oct 10-11, 2014
Amelia Island, FL

Advances in Pathophysiology and Emerging Novel Therapeutic Strategies
Oct 10-11, 2014
Boston, MA

30th Annual Echocardiography in Pediatric and Adult Congenital Heart Disease
Oct 15-19, 2014
Phoenix, AZ

Advanced Catheter Ablation Course: New Tips, Techniques and Technologies for Complex Arrhythmias
Oct 18-21, 2014
San Francisco, CA

24th Annual Cases in Echocardiography, Cardiac CT and MRI
Oct 22-25, 2014
Napa, CA

Coronary Artery Disease: Prevention, Detection and Treatment
Nov 21-23, 2014
Las Vegas, NV

Echo on Marco Island: Case-Based Approach
Dec 4-7, 2014
Marco Island, FL

3rd Annual Mayo Clinic ECG and Heart Rhythm Course: A Case-Based Approach
Dec 4-7, 2014
Phoenix, AZ

The Heart Beat of Cardiology: Practical Application of Echocardiography
Dec 11-13, 2014
Chicago, IL

SYMPOSIUM
Mayo Clinic Satellite Educational Symposium at ASE 2014
Case Studies in Valvular Heart Disease: An Evidence-Based, Real-Life Interactive Experience
Jun 20, 2014
Portland, OR

Mayo Clinic Satellite Educational Symposium at AHA 2014
Nov 15-19, 2014
Chicago, IL

Symposia to be announced

CARDIOVASCULAR SELF-STUDY
https://cardiovascular.education-registration.com/selfstudy

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Mayo Clinic welcomes inquiries and referrals, and a request to a specific physician is not required to refer a patient.

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Resources
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Clinical trials, CME, Grand Rounds, scientific videos, and online referrals