Valve replacement with a prosthetic mechanical or tissue valve is the only treatment for many diseased cardiac valves. Thrombosis of a prosthetic valve is potentially life-threatening, resulting in hemodynamically severe stenosis or regurgitation (Figures 1 and 2). “Thrombotic risk is related to the type of valve, position of the valve, and adequacy of anticoagulation,” according to Vuyisile T. Nkomo, MD, MPH, director of the Valvular Heart Disease Clinic at Mayo Clinic in Rochester, Minnesota. “Other factors include thrombogenicity of the prosthetic material, shear stress, and localized areas of abnormal flow.” Therefore, individuals with mechanical valves require lifelong anticoagulation with warfarin along with aspirin, whereas those with tissue valves usually require anticoagulation for only 3 to 6 months followed by lifelong aspirin therapy. The target international normalized ratio (INR) for individuals with bileaflet or current-generation single tilting disk mechanical aortic valves is 2.5 if they have no risk factors for thromboembolism and 3.0 if they have a ball-cage mechanical valve (because of the associated higher risk of thrombosis) or risk factors for thromboembolism such as atrial fibrillation, left ventricular systolic dysfunction, prior thromboembolism, or hypercoagulable state. The goal INR is 3.0 (range, 2.5 to 3.5) for patients with mechanical mitral valves and 3.5 to 4.0 for patients with mechanical tricuspid valves. The incidence of mechanical valve thrombosis is 0.5% to 8% for left-sided mechanical valves and 20% for right-sided valves (likely attributable to lower flow and gradient). Although uncommon, tissue valve thrombosis can occur.
Signs and symptoms of mechanical valve thrombosis may include muffled mechanical heart sounds, a new murmur, dyspnea, heart failure, and cardiogenic shock. Thrombosis of right-sided valves causes right-sided heart failure, characterized by swelling of the legs and/or abdomen without pulmonary congestion. The onset of symptoms may be progressive or acute, depending on the rate and degree of stenosis or regurgitation. Another potential difficulty is thromboembolism resulting in transient ischemic attack, stroke, or pulmonary embolism. Therefore, valve thrombosis should be suspected and immediately investigated in anyone with a mechanical valve who develops new auscultatory findings, dyspnea, heart failure, peripheral edema, thromboembolism, or shock.

**Thrombus, Vegetation, or Pannus?**

Both transthoracic and transesophageal echocardiography should be performed when there is suspicion of abnormal valve prosthesis function (Figures 3 and 4). There are some distinguishing features between thrombus and pannus in terms of when they occur after mechanical valve replacement surgery and the echocardiographic appearance. Inadequate anticoagulation with warfarin should raise suspicion of thrombus. Pannus formation usually occurs many years after mechanical valve replacement, compared with thrombus, which may occur at any time. Pannus is more commonly associated with mechanical valves in the aortic position but can occur in association with any mechanical valves. Obstruction due to pannus tends to develop slowly over time, and symptom onset is usually more gradual. Obstruction related to thrombus is typically more acute.

Transthoracic echocardiography is helpful in detecting the presence and degree of obstruction and regurgitation but is inadequate in distinguishing pannus from thrombus. This distinction can be more accurately assessed by transesophageal echocardiography. Thickened valve leaflets and an increased gradient are suspicious for thrombosis. Visually, thrombus tends to be larger and more mobile than pannus, but the best distinguishing feature between the two is lower video intensity of the thrombus compared with pannus, which can be discerned by an experienced echocardiologist. Endocarditis should be considered when a mobile echo is seen in association with a prosthetic valve or the patient is febrile with abnormal prosthesi sh function.

Acoustic shadowing can impair both transthoracic and transesophageal image quality. Imaging in the cardiac catheterization laboratory with fluoroscopy or imaging with computed tomography may also be helpful in the diagnosis of abnormal mechanical leaflet motion when imaging is not adequate with transthoracic and transesophageal echocardiography.

**Treatment of Valve Obstruction**

**Mechanical Valves**

Management is dictated by the cause of obstruction (pannus versus thrombus), the size, and the severity of symptoms. Severe mechanical valve obstruction caused by pannus requires repeat open heart surgery to remove the pannus or to replace the valve. Options for treating symptomatic obstruction of mechanical valves from thrombus include intravenous heparin, thrombolytics, or repeat surgery.

**Left-Sided Mechanical Valves**

Valve obstruction from a small thrombus (less than 1 cm in diameter or 0.8 cm² in area), recent onset (less than 14 days), and associated with mild symptoms (New York Heart Association [NYHA] class I-II) can be treated initially with a trial of 24 to 48 hours of intravenous unfractionated heparin with a goal activated partial thromboplastin time (APTT) of 1.5 to 2 times the control value. The patient should be monitored clinically, transthoracic echocardiography should be performed every 2 to 4 hours, and transesophageal echocardiography should be performed daily to assess the valve.

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**Figure 3.** 2-Dimensional transesophageal echocardiogram of bileaflet mechanical mitral valve prosthesis. Note both leaflets in closed position in systole (left, arrows), with opening of only 1 disk in diastole (right, yellow arrow). The red arrow denotes the fixed disk. LA, left atrium; LV, left ventricle.

**Figure 4.** 3-Dimensional transesophageal echocardiogram. Left atrial view of bileaflet mechanical mitral valve prosthesis. Note both leaflets in closed position in systole (left, arrows), with opening of only 1 disk in diastole (right, yellow arrow). The red arrow marks the fixed disk.
status. Improvement in valve function and gradient should be followed by warfarin and continued intravenous heparin until the INR is in the range of 3 to 4 for aortic prostheses and 3.5 to 4.5 for mitral prostheses.

If there is no improvement in valve function and gradient after 24 hours, thrombolytic therapy with recombinant tissue plasminogen activator (tPA) (10-mg intravenous bolus followed by 90-mg intravenous infusion over 2 hours or, alternatively, 20-mg intravenous bolus followed by 30-mg infusion over 3 hours) should be considered. Successful thrombolytic therapy should be followed by warfarin and intravenous unfractionated heparin until the INR is 3 to 4 for aortic valve prostheses and 3.5 to 4.5 for mitral prostheses. Patients in whom thrombolytic therapy is partially successful (the valve gradient is improved but not normalized) present a challenge. Options include both subcutaneous unfractionated heparin twice daily to achieve an APTT of 1.5 to 2 times control and warfarin therapy with a target INR of 2.5 to 3.5 for 3 months.

Emergency surgery is recommended for patients with severe symptoms (NYHA class III-IV) and left-sided valve thrombosis, regardless of thrombus size. Emergency surgery is recommended if the thrombus size is large (more than 1 cm in diameter or greater than 0.8 cm² in area), regardless of symptoms. The rationale for avoiding thrombolytic therapy with large thrombus burden is the marked increased risk of thromboembolism. Thrombolytic therapy can be considered if the risk precludes surgical intervention.

The overall risk of bleeding and thromboembolism with fibrinolytic therapy of left-sided valves is 17.8% and is directly related to thrombus size. Patients with small thrombi are at lower risk of complications. Contraindications to thrombolytic therapy include a history of intracranial bleeding, recent cranial trauma, gastrointestinal or genitourinary bleeding within 21 days, hemorrhagic retinopathy, the presence of large, mobile thrombi, severe hypertension, hypotension or cardiogenic shock, or major surgery within the previous 2 weeks.

Right-Sided Mechanical Valves
A trial of intravenous heparin followed by thrombolytic therapy (in the absence of contraindications) is the mainstay of treatment of right-sided mechanical valve thrombosis. Successful thrombolytic therapy should be followed by warfarin and intravenous unfractionated heparin until INR is in the range of 3.5 to 4.5. Partially successful thrombolytic therapy may be followed by subcutaneous unfractionated heparin twice daily to achieve an APTT of 1.5 to 2 times control or 55 to 80 seconds. Pulmonary embolus is a potential complication, although usually asymptomatic. Surgery should be considered if heparin and thrombolytic therapy fail.

Tissue Valves
Tissue valves are at much lower risk of thrombosis compared with mechanical valves. The typical clinical scenario is an increasing pressure gradient across the prostheses, typically within the first 5 years after surgery, although late cases have been described. Thrombus is usually located in the cusp of the tissue prosthesis leaflets on the downstream side, and it is difficult to visualize, particularly when involving the aortic valve tissue prosthesis. “The literature suggests that porcine tissue valves tend to thrombose at higher rates than pericardial tissue valves, but this may be because there have been so many more porcine valves implanted,” according to Sorin V. Pislaru, MD, PhD, a cardiologist at Mayo Clinic in Rochester. Transesophageal echocardiography should be considered in all patients with increased gradients in whom the transthoracic echocardiographic study is suspicious for tissue valve obstruction or degeneration.

Treatment of Tissue Valve Thrombosis
Anticoagulant therapy with warfarin with a goal INR of 2 to 3 is effective in treating tissue valve thrombosis in the majority of patients. Heparin (unfractionated or low molecular weight) can be considered when rapid anticoagulation is desired (eg, in patients with large thrombus burden, mobile thrombus, uncertain hemodynamic status). However, patients who exhibit hemodynamic instability should be considered for emergent surgery or thrombolytic therapy. In a special category are patients who are already on anticoagulant therapy; we recommend a trial of warfarin anticoagulation at a higher INR target in the range of 2.5 to 3.5. Novel oral anticoagulants have not been used in patients with bioprosthetic valves; their role in bioprosthetic thrombosis is entirely unknown, and they cannot be recommended at this time.

Summary
Cardiac valve replacement is increasingly common as a result of valvular disease in aging populations. Prompt identification of valve dysfunction and timely treatment mitigate the risk of catastrophic outcomes. Mayo Clinic cardiologists and cardiac surgeons are always available to consult by phone, review images, and evaluate these patients on an urgent basis.
New Anticoagulation Options for Patients With Nonvalvular Atrial Fibrillation

Warfarin has been the sole oral anticoagulant in use for many decades. Multiple studies have demonstrated the superiority of therapeutic warfarin anticoagulation in stroke prophylaxis compared with various doses of aspirin and other platelet inhibitors and combinations of platelet inhibitors and low-dose warfarin in high-risk patients with atrial fibrillation. Although guidelines suggest a target international normalized ratio (INR) of 2.5 (range, 2.0 to 3.0) for this indication, only about 50% to 60% of patients have an INR within the recommended range in usual clinical practice. Novel oral anticoagulants (NOACs) have provided another treatment option for these individuals. “While these agents have been approved previously for prevention and treatment of deep venous thrombosis (DVT), recent clinical trials have demonstrated their noninferiority compared with warfarin in the prevention of thromboembolic stroke in patients with nonvalvular atrial fibrillation,” according to Robert D. McBane, MD, a cardiologist at Mayo Clinic in Rochester, Minnesota.

General Characteristics of NOACs

Vitamin K antagonists such as warfarin inhibit the carboxylation of all vitamin K–dependent procoagulant factors (II, VII, IX, and X), but they also have the “off-target” effect of inhibiting protein C and protein S (Figure). NOACs target specific proteins in the coagulation cascade; dabigatran inhibits thrombin, and rivaroxaban, apixaban, and edoxaban are all direct inhibitors of factor Xa. Factor Xa is the point at which the intrinsic and extrinsic pathways converge to form the final common pathway of prothrombin activation.

All NOACs have rapid onset (1-3 hours) and, as a result, do not require bridging; they all have similar half-lives (7-15 hours). They all exhibit some degree of renal metabolism. Hepatic cytochrome p450 3A4 (CYP3A4) is an important pathway of metabolism of all NOACs except for dabigatran. Strong inducers of this hepatic pathway include carbamazepine, phenytoin, rifampin, St John’s wort, and tipranavir-ritonavir combination therapy. Strong inhibitors include itraconazole, ketoconazole, lopinavir-ritonavir combination therapy, indinavir, and voriconazole.

Summary of Clinical Trials

The results of 4 large clinical trials, each evaluating 1 of the 4 agents approved by the US Food and Drug Administration (FDA) (dabigatran, rivaroxaban, apixaban, and edoxaban), have been published. All 4 agents demonstrated similar efficacy and improved safety (especially apixaban and edoxaban) compared with warfarin, despite significant differences in baseline patient characteristics, including CHADS2 score, history of congestive heart failure, history of prior stroke, percentage of therapeutic time in warfarin group, allowance of antiplatelet agents in the respective protocols, and duration of follow-up. “However, patients with severe renal failure were excluded from all trials,” notes Waldemar E. Wysokinski, MD, PhD, a cardiologist at Mayo Clinic in Rochester. “All trials had relatively high discontinuation rates, which had a negative impact on the reported incidence of thromboembolic events and a favorable impact on the reported incidence of major bleeding. These limitations need to be kept in mind when evaluating trial results.”

RE-LY (Randomized Evaluation of Long-Term Anticoagulation Therapy, 2009)

This open, blinded-endpoint study compared dabigatran (thrombin inhibitor), 110 mg or 150 mg twice daily, to open-label, dose-adjusted warfarin. A total of 18,113 patients were enrolled. Inclusion criteria included CHADS score of 1 or higher. There was no provision for dose adjustment. Follow-up was nearly 2 years. INRs were in the therapeutic range in the warfarin group 64% of the time on average. The rate of all strokes in the 150-mg dabigatran group was less than that in the 110-mg dabigatran and the warfarin groups. The rate of extracranial hemorrhage was similar in all 3 groups. (Stuart J. Connolly et al. Dabigatran versus warfarin in patients with atrial fibrillation. N Engl J Med. 2009;361:1139-51)

ROCKET AF (Rivaroxaban Once Daily Oral Direct Factor Xa Inhibition Compared With Vitamin K Antagonism for Prevention of Stroke and Embolism Trial in Atrial Fibrillation, 2011)

This double-blinded, double-dummy study compared rivaroxaban (direct inhibitor of factor Xa), 20 mg once daily, with dose-adjusted warfarin. A total of 14,264 patients were enrolled. Inclusion criteria included CHADS2 score of 2 or higher. There was no provision for dose adjustment. INRs were in the therapeutic range in the warfarin group 55% of the time on average. Follow-up was nearly 2 years. Three different protocol-specified analyses were performed:
**Figure. Activation of clotting factors that lead to fibrin-clot formation.**

- **Intrinsic (contact activation pathway)**: XII, XIIa, XI, Xa, IXa, IX, VIIIa, VIIa, TF
- **Extrinsic (tissue factor activation pathway)**: X, Va, Thrombin, Fibrinogen, Fibrin

**ARISTOTLE (Apixaban for Reduction in Stroke and Other Thromboembolic Events in Atrial Fibrillation, 2011)**

This double-blinded, double-dummy study compared apixaban (direct inhibitor of factor Xa), 5 mg twice daily, with dose-adjusted warfarin. A total of 18,201 patients were enrolled. Inclusion criteria included CHADS score of 1 or higher. INRs were in the therapeutic range in the warfarin group 62% of the time. Five percent of patients had allowed dose adjustment. Follow-up was nearly 2 years. Apixaban reduced the risk of stroke or systemic embolism by 21% and the risk of major bleeding by 31%. Importantly, the apixaban-treated group had a significant reduction in all-cause death compared with the warfarin group (11%). This trial was the first to conclusively demonstrate improved overall mortality with NOAC treatment. (Christopher B. Granger et al. Apixaban versus warfarin in patients with atrial fibrillation. N Engl J Med. 2011;365:883-91)

**ENGAGE AF-TIMI 48 (Effective Anticoagulation With Factor Xa Next Generation in Atrial Fibrillation–Thrombolysis in Myocardial Infarction 48, 2013)**

This double-blinded, double-dummy study compared edoxaban (direct inhibitor of factor Xa), 30 mg or 60 mg, once daily, with dose-adjusted warfarin. A total of 21,105 patients were enrolled. Inclusion criteria included CHADS score of 2 or higher. INRs in the warfarin group were therapeutic 68.4% of the time. In the edoxaban group, 25% of patients had allowed, postrandomization dose adjustment. Follow-up was nearly 3 years. Edoxaban in both doses was not inferior to warfarin for stroke prevention but showed a better safety profile. (Robert P. Giugliano et al. Edoxaban versus warfarin in patients with atrial fibrillation. N Engl J Med. 2013;369:2093-2104)

**Individual Agents**

**Dabigatran (Pradaxa)**

Dabigatran requires twice-daily dosing. Slight fluctuations in gastric acidity may impact absorption of the prodrug. Thus, the active ingredient is incorporated into tartaric acid–coated spherules within the capsules, and the capsules must be swallowed whole. The tartaric acid may be responsible for the gastric upset experienced by 5% to 10% of patients. The capsules are stored in a blister package until use, as they are susceptible to degradation by ambient moisture. The prodrug is converted to the active form by a serum esterase and therefore is not dependent on the hepatic cytochrome p450 system; however, P-glycoprotein (P-gp) inhibitors such as quinidine, verapamil, and amiodarone increase serum concentrations of dabigatran.

**Rivaroxaban (Xarelto)**

An advantage of rivaroxaban is once-daily dosing. Hepatic CYP3A4 is an important pathway of metabolism, and the effects of other drugs that impact this pathway need to be considered. At 20-mg doses (15 mg for patients with creatinine clearance <50 mL/min), rivaroxaban should be taken with food to achieve better bioavailability.

**Apixaban (Eliquis)**

Apixaban requires twice-daily dosing. Most of the hepatic clearance of apixaban occurs without metabolism. Thus, apixaban can be coadministered with drugs that are strong CYP3A4 and P-gp inhibitors, but at a reduced dose of 2.5 mg twice daily.

**Edoxaban (Savaysa)**

Edoxaban has recently received FDA approval for this indication. An advantage is once-daily dosing, and it should be taken with food to optimize absorption. The FDA has included a boxed warning stating that edoxaban is less effective than warfarin in preventing stroke in patients with creatinine clearance higher than 95 mL/min, possibly due to the fact that 50% to 60% of the drug is excreted renally. It is approved for treating DVT and pulmonary embolism (PE) as well as secondary DVT and PE prophylaxis.

**Knowledge Gaps**

Because of variations in inclusion and exclusion criteria in the 4 major clinical trials, the appropriate use of NOACs in patient subgroups is unknown. There are no data regarding the use of NOACs in pediatric and pregnant patients; patients with prior history of intracranial, intracocular, spinal, or traumatic arterial bleeding; and patients with severe anemia or thrombocytopenia. All of these subgroups were restricted from clinical trials.

An early concern not addressed in clinical trials is the lack of antidotes to rapidly reverse the anticoagulant effects of NOACs in the case of life-threatening hemorrhage (especially intracranial) or surgery. For unclear reasons, the incidence of intracranial hemorrhage was lower in the NOAC–treated groups than in the warfarin–treated groups in all 4 trials, possibly due to the single-target effect with NOACs versus the multiple factors affected by warfarin. However, it should be noted that the hemorrhagic rate in patients on warfarin in these 4 trials was higher than the rate documented in the Canadian registry, which likely better represents “real life.” Additionally, there are no data suggesting that reversibility is associated with improved outcome in patients with severe bleeding. Preliminary results from a preplanned interim
Both at Mayo Clinic in Rochester. the Division of Cardiovascular Surgery, Charanjit S. Rihal, MD, MBA, chair of the Division of Cardiovascular Diseases, and Joseph A. Dearani, MD, chair of the Division of Cardiovascular Surgery, both at Mayo Clinic in Rochester.

For those individuals on a stable, established warfarin regimen, there is no need to change. If a change is contemplated, Drs McBane and Wysokinski suggest that the following factors be taken into consideration:

- The only agent to have superior efficacy in reduction of ischemic stroke is dabigatran, 150 mg twice daily.
- For patients at increased risk of bleeding apixaban demonstrated a consistent reduction in bleeding across all age groups studied, regardless of indication for anticoagulation.
- Edoxaban, 30 mg daily, is the only NOAC that has demonstrated specifically a reduced risk of gastrointestinal bleeding compared with warfarin.
- Once-daily dosing improved compliance (rivaroxaban and edoxaban).

Structural heart disease encompasses disorders characterized by abnormalities of the major central cardiac structures, the result of either congenital or acquired factors. Treatment of this group of disorders has traditionally necessitated open heart surgery, but now many of these conditions can be managed with transcatheter-based therapies or minimally invasive and robotic techniques in carefully selected patients. These less invasive options provide the opportunity to treat both high-risk patients whose conditions would otherwise be inoperable and low-risk patients who return more rapidly to normal activities following a less invasive approach. These therapies also offer the possibility of earlier intervention, thereby potentially altering the natural history of the disease.

The field is new and born of innovation. It is the result of advances in transcatheter-based therapies, improved diagnostic and procedural imaging, and cutting-edge technology. More exciting is the prospect of actually preventing these structural disorders from occurring by applying early genetic diagnosis and therapy or even modifying the natural history of disease using stem cells and cardiac tissue regeneration. While these opportunities are exciting, challenges hamper the translation of these ideas into treatments for patients.

To that end, the Mayo Clinic Innovation Summit 2014 was dedicated to structural heart disease. Attendees learned the Mayo perspective on the opportunities and challenges in the next 5 years in the fields of cardiac replacement, repair, and regeneration. Highlights of the summit included an address from John H. Noseworthy, MD, chief executive officer of Mayo Clinic. Dr Noseworthy highlighted the importance and the history of innovation at Mayo Clinic. He cited examples such as development of the first integrated medical record, development of the G-suit, introduction of the first CT scanner, development of MR elastography, and use of DNA fingerprinting to detect early-stage colon cancer.

Jeffrey W. Bolton, chief administrative officer of Mayo Clinic, described how Mayo is actively fostering the commercialization of innovation. This is being achieved through 1) policy changes that break down barriers experienced by physician inventors, 2) funding opportunities through grants from the Center for Innovation, the Venture Innovation Program, and the President’s Discovery and Translation Fund, and 3) promotion of an ecosystem that fosters innovation and entrepreneurship in the local community. He also highlighted Mayo’s success—in the past 8 years, $30 million has funded 191 new technologies, 101 of which have been commercialized.

Paul Yock, MD, the Martha Meier Weiland Professor of Medicine and director of biosignals at Stanford University, delivered the keynote address, “The Radical New World Order in Medical Technology Innovation.” He noted the historic changes in medical technology and innovation in the United States and internationally. In the developing world, health care markets are growing rapidly, but within a cultural framework of affordability, while increasing cost pressures are barriers to new technology in developed countries. Dr Yock proposed that there will likely be a “virtuous cycle” that will not only bring technology developed outside the United States here, but will also result in “infecting” US innovators to “bring a sense of affordability into discovery-driven research.”

Several important themes emerged from the Summit:
- Health care is no longer immune to economic forces. Value is the key.
- Incremental change is not good enough. Disruption is difficult but needed.
• Patients, regulators, and payers need to be educated.
• New models of funding are required to bring together innovators, industry representatives, venture capitalists, and philanthropists early on to support new technologies from inception through maturation.

The summit was an exciting learning experience and facilitated collaboration that will act as a springboard to foster innovative efforts around disease-specific teams working together to define the next generation of structural heart therapies at Mayo Clinic.

RECOGNITION: NAMED PROFESSORS

Consultants are appointed to named professorships through nomination and endorsement of their peers and then confirmed by Mayo Clinic senior leadership. Appointed individuals are recognized for distinguished achievement in their specialty areas and service to the institution.

The professorships are named in honor of Mayo Clinic benefactors who recognize Mayo’s role in pursuing answers in health and medicine. The gifts may be unrestricted or focused on a specific medical area and are held in endowment. All income from the endowed professorships supports Mayo Clinic medical education and research.

Back row, left to right:
David R. Holmes Jr, MD
Edward W. and Betty Knight Scripps Professor of Cardiovascular Medicine in Honor of Dr George M. Gura, Jr
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Raymond J. Gibbons, MD
Arthur M. and Gladys D. Gray Professor in Honor of Dr Howard A. Andersen
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Robert E. Safford, MD, PhD
Barbara Woodward Lips Professor
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Thom W. Rooke, MD
John and Posy Krehbiel Professor of Vascular Medicine
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Rick A. Nishimura, MD
Judd and Mary Morris Leighton Professor of Cardiovascular Diseases and Hypertension in Honor of Dr Alexander Schriger
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Andre Terzic, MD, PhD
Marriott Family Professor of Cardiovascular Research
Consultant in Cardiovascular Diseases and Internal Medicine, Molecular Pharmacology and Experimental Therapeutics, Pharmacology, and Medical Genetics
Professor of Medicine and Pharmacology, Mayo Clinic College of Medicine

Douglas L. Packer, MD
John M. Nasseff Sr Professor of Cardiology in Honor of Dr Burton Ostroumovitch
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Front row, left to right:
Charanjit S. Rihal, MD, MBA
William S. and Ann Atherton Professor of Cardiology Honoring Robert L. Frye, MD
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Veronique L. Roger, MD
Elizabeth C. Lane, PhD, and M. Nadine Zimmerman, PhD, Professor of Internal Medicine
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Mayo Clinic College of Medicine

Erik L. Rittman, MBBS, PhD
Ralph B. and Ruth K. Ahlman Professor
Consultant in Cardiovascular Diseases and Internal Medicine and Physiology and Biomedical Engineering
Professor of Medicine and Physiology, Mayo Clinic College of Medicine

Hartzell V. Schaff, MD
Stuart W. Harrington Professor of Surgery
Consultant in Cardiovascular Surgery
Professor of Surgery, Mayo Clinic College of Medicine

Michael J. Ackerman, MD, PhD
Windland Smith Rice Cardiovascular Genomics Research Professor
Consultant in Cardiovascular Diseases and Internal Medicine
Professor of Medicine, Pediatrics and Pharmacology, Mayo Clinic College of Medicine

John C. Burnett Jr, MD
Marriott Family Cardiovascular Research Professor
Consultant in Cardiovascular Diseases and Internal Medicine and Physiology and Biomedical Engineering
Professor of Medicine and Physiology, Mayo Clinic College of Medicine
Cardiology Update 2015: The Heart of the Matter
Aug 6-9, 2015, Sedona, AZ

Success With Failure: Strategies for the Evaluation and Treatment of Heart Failure in Clinical Practice
Aug 10-12, 2015, Dana Point, CA

Electrophysiology Review for Boards and Recertification
Aug 14-16, 2015, Rochester, MN
Aug 21-26, 2015, Rochester, MN

20th Annual Mayo Cardiovascular Review Course for Cardiology Boards and Recertification
Aug 21-26, 2015, Rochester, MN
Aug 26, 2015 ABIM/MOC Modules: 2014 Cardiovascular Update and 2015 Cardiovascular Update; MOC points available with online course credit

Challenges in Clinical Cardiology: A Case-Based Update
Sep 18-20, 2015, Chicago, IL

Echo in the City of Rivers: Practical Review of Myocardial and Ischemic Disease
Sep 19-20, 2015, Pittsburgh, PA

Mayo Clinic Interventional Cardiology Board Review
Sep 25-27, 2015, Rochester, MN
Sep 25, 2015 ABIM/MOC Modules: 2014 Interventional Cardiology and 2015 Interventional Cardiology; MOC points available with online course credit

Oct 2-6, 2015, Washington, DC

31st Annual Echocardiography in Pediatric and Adult Congenital Heart Disease
Oct 6-11, 2015, Phoenix, AZ

25th Annual Cases in Echocardiography, Cardiac CT and MRI
Oct 21-24, 2015, Napa, CA

Mayo Clinic Update in Echocardiography: Role of Echo From Prevention to Intervention
Nov 12-15, 2015, Scottsdale, AZ

Clinical and Laboratory Update in Thrombosis and Anticoagulation
Nov 18-20, 2015, Scottsdale, AZ

Coronary Artery Disease: Prevention, Detection, and Treatment
Nov 20-22, 2015, Las Vegas, NV

5th Annual Echo on Marco Island: Case-Based Approach
Dec 3-6, 2015, Marco Island, FL

8th Annual The Heart Beat of Cardiology: Practical Application of Echocardiography
Dec 10-12, 2015, Chicago, IL

Cardiovascular Imaging 2016
Jan 7-10, 2016, Orlando, FL

Mayo Clinic Cardiology Update at South Beach: A Focus on Prevention
Jan 17-20, 2016, Miami, FL

Mayo Clinic Cardiovascular Reviews in Bahrain
Jan 27-30, 2016, Manama, Bahrain

Arrhythmias and the Heart: A Cardiovascular Update
Feb 1-5, 2016, Maui, HI

Hawaii Heart: Case-Based Clinical Decision Making Using Echocardiography and Multimodality Imaging
Feb 7-12, 2016, Kauai, HI

Cardiovascular Conference at Snowbird
Feb 12-15, 2016, Snowbird, UT

5th Annual Innovations in Valve and Structural Heart Disease
Feb 15-17, 2016, Nassau, Bahamas

21st Annual Cardiology at Cancun
Feb 22-16, 2016, Cancun, Mexico

23rd Annual Echocardiographic Workshop on 2-D and Doppler Echocardiography at Vail
Mar 7-10, 2016, Vail, CO

Echo Revolution: Adult Echocardiography for Physicians and Sonographers
Mar 12-16, 2016, New York, NY

Heart Failure Management for Nurse Practitioners, Physician Assistants, and Primary Care Providers
Mar 18-20, 2016, Lake Buena Vista, FL

Case Studies From the Heart of Manhattan: A Mayo Clinic Cardiovascular Update
Apr 7-9, 2016, New York, NY

Echo Fiesta: An In-Depth Review of Adult Echocardiography for Sonographers and Physicians
Apr 7-10, 2016, San Antonio, TX

CARDIOVASCULAR SELF-STUDY
https://cardiovascular.education-registration.com/selfstudy
www.mayo.edu/cme/cvselfstudy

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