SECTION 1

Cardiovascular Disease: Past, Present, and Future

1. A History of the Cardiac Diseases, and the Development of Cardiovascular Medicine as a Specialty ............................................. 3
2. The Global Burden of Cardiovascular Diseases ............................................. 19
3. Assessing and Improving the Quality of Care in Cardiovascular Medicine .......................................................... 53
CHAPTER 1

A HISTORY OF THE CARDIAC DISEASES, AND THE DEVELOPMENT OF CARDIOVASCULAR MEDICINE AS A SPECIALTY

Robert A. Harrington, Mark E. Silverman*, and Charles F. Wooley*

The history and our still emerging understanding of the heart are a remarkable story, with origins in antiquity, centered initially on clinical observations. Thought at one time to be the center of the soul and impervious to disease, the heart was long a source of mystery and wonder, studied in science and fascinated about in literature and the arts. Most historians agree that William Harvey’s discovery of the circulation of blood in the early 17th century is a good place to start the modern history of cardiovascular medicine. Following Harvey, cardiology pursued a pathway of descriptive anatomy and pathology in the 17th and 18th centuries, auscultation and its correlations in the 19th century, an understanding of cardiac disease and its pathophysiology in the second half of the 19th and first half of the 20th centuries, and major advances in the diagnosis and treatment of heart disease from there into the 21st century. What has emerged in the 21st century is a medical specialty with incredible tools of diagnosis, including blood biomarkers and multiple imaging modalities; numerous medical treatment options that include drugs, biologics, and devices; and surgical options involving complex operations that both repair and replace dysfunctional anatomy.

What has also emerged in the 21st century is a far less positive story; the growing global epidemic of atherosclerotic heart disease and its ischemic complications; an epidemic created by the exportation of tobacco products around the world; a change in dietary patterns with decreasing amounts of fresh fruits and vegetables; and an increase in more sedentary lifestyles, in some ways facilitated by technology. The United Nations and the World Health Organization have identified the noncommunicable diseases as major global public health problems that threaten or limit the overall financial and social stability of the global community in both developed and developing nations. The increasing burden of obesity has led to major increases in diabetes, which is expected to increase the incidence of cardiac diseases. The aging of the population has also been associated with a marked increase in the incidence of atrial fibrillation and the attendant risk of embolic stroke.

The introduction of the first instruments of precision—blood pressure measurement, the chest x-ray, and the electrocardiogram—in the 1890s and early 20th century, led to the creation of the specialty of cardiology. Since the 1950s, following the advent of cardiac catheterization and surgery, cardiology has evolved into multiple, highly specialized disciplines focusing on coronary artery disease, heart failure, arrhythmias, imaging, and preventive care. Early diagnosis of cardiac risk and aggressive medical treatment of cardiac diseases coupled with increasing attention to prevention have led to a gradual decrease in mortality for cardiac disease. A hallmark of cardiovascular medicine in the early 21st century has been its emergence at the forefront of the evidence-based medicine movement with an intense commitment to the clinical practice guidelines by the major professional societies and public health organizations. Moving toward 2020, we see the adoption of digital and mobile technologies in medical care for prevention, diagnosis, and treatment. At the forefront of these movements is a focus on cardiac health and fitness and the potential for more tools for patients to directly monitor and manage their cardiac disorders, including heart failure, arrhythmias, and hypertension. There is also the issue of how to use “big data” in both research and the clinical management of cardiovascular disease. This will include routinely incorporating genomics and other “omics” in the assessment of cardiovascular risk and disease.

Many of the initial key discoveries are now recalled as eponyms attached to diseases or physical signs. As the number of investigators has grown exponentially and internationally, it is increasingly difficult to assign singular credit to contributions for which many are ultimately responsible. Taking all of these considerations into account, we have chosen to provide a condensed narrative by subject, selectively

---

*Deceased
highlighting important events and key figures in the grand story of cardiovascular medicine written by our illustrious predecessors.2,5,10,26

WILLIAM HARVEY AND THE CIRCULATION OF THE BLOOD

Early civilizations considered the heart to be a source of heat and believed that the blood vessels carried pneuma, the life-sustaining spirit of the vital organs. This concept was mostly fully elaborated by Claudius Galen (AD 130-200), whose erroneous teachings were entrenched for 1300 years, until Andreas Vesalius corrected his anatomy (1543), and William Harvey proposed that blood circulates because of the force of the heart (1616).21

Harvey’s discovery of the circulation of blood (Fig. 1–1) is considered to mark the beginning of modern cardiology as well as the introduction of experimental observation. Starting in 1603, Harvey dissected the anatomy and observed the motion of the cardiac chambers and flow of blood in more than 80 species of animals. His experimental questions “to seek unbiased truth” can be summarized in the following questions. What is the relationship of the motion of the auricle to the ventricle? Which is the systolic and which is the diastolic motion of the heart? Do the arteries distend because of the propulsive force of the heart? What purpose is served by the orientation of the cardiac and venous valves? How does blood travel from the right ventricle to the left side of the heart? Which direction does the blood flow in the veins and the arteries? How much blood is present and how long does its passage take?

After many experiments and without knowledge of the capillary circulation of the lungs, which was not known until 1661, Harvey stated: “It must of necessity be concluded that the blood is driven into a round and that it moves perpetually; and hence does arise the action or function of the heart, which by pulsation it performs.” This was published in 1628 as Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus.27 This revolutionary concept eventually became accepted in Harvey’s lifetime and remains the foundation of our understanding of the purpose of the heart.

THE CARDIAC EXAMINATION

THE ARTERIAL PULSE

Until the 17th century, the clinical examination consisted of palpating the pulse and inspecting the urine to reveal disease and predict prognosis. In Chinese acupuncture, the pulse was timed according to the physician’s respiration whereas digital pressure was applied to elicit information. Galen wrote 18 books on the arterial pulse in the 2nd century, providing elaborate descriptions that influenced clinical practice well into the 18th century.22 The 1-minute pulse watch, invented by Floyer in 1707, offered the first opportunity to measure the heart rate accurately; however, this did not become a routine part of medical practice until the mid-19th century.7 Since the 19th-century observations of Dominic Corrigan, the carotid arterial pulse has been linked to aortic valve disease and is essential for timing systole at the bedside. In 1847, Carl Ludwig in Leipzig invented the kymograph, a pulse writer that would elevate physiology to a new level and be used to inscribe arterial and venous pulses. Pulsus alternans was described by Ludwig Traube in 1872, and Adolf Kussmaul called attention to the paradoxical pulse in 1873, noting that the arterial pulse could transiently disappear on inspiration even though the heart sounds were still audible. Before electrocardiography, arterial pulse recordings were applied to diagnose arrhythmias, as shown by James Mackenzie in The Study of the Pulse (1902).27

PERCUSSION

In 1761, Leopold Auenbrugger, a Viennese physician, published a book proposing “percussion of the human thorax, whereby, according to the particular sounds thence elicited, an opinion is formed of the internal state of that cavity.”28 He had observed his father, an innkeeper, use this technique to check the wine levels in his casks. Percussion was reintroduced by Jean-Nicolas Corvisart in early 19th-century France and became an essential addition to the chest examination until it was mostly supplanted by the chest x-ray.

THE JUGULAR VENOUS PULSE

Jugular venous wave recording was initiated in France, in the mid-19th century, by Pierre-Carl Potain. In the 1870s, Mackenzie sought to interpret arrhythmias by understanding arterial and venous pulse waves. Using a kymograph, then an ink-writing polygraph, Mackenzie applied his intuitive skills to the interpretation of jugular waves, which he labeled “a, c, and v.”29 Thomas Lewis, a disciple of Mackenzie, described the technique of bedside assessment of jugular venous pressure relative to the sternal angle in 1930.

AUSCULTATION

Auscultation of the chest was first practiced by Hippocrates (460-370 BC), who applied his ear directly to the chest. The invention of the wooden monaural stethoscope (Greek: stethos, chest; skopein, to view or to see) by René Laennec in Paris (1816) introduced a powerful, although initially difficult, technique to listen to cardiovascular sound.29,30 This method spread to Europe and Great Britain—where it was promoted by Skoda, Stokes, Hope, Williams, and others—and to America, where Austin Flint became its champion. By the mid-19th century, the stethoscope was established as an indispensable tool for the examination of the heart and lungs. Diagnoses based on percussion and auscultation were subjected to the critical analysis of the autopsy by Corvisart, Laennec, Kotkansky, and Skoda, and murmurs were assigned according to their underlying pathology. Symptoms not supported by auscultatory or autopsy findings were often thought to be functional or unreliable. The stethoscope evolved from a monaural to a binaural device in 1855, and separate heads were developed by Bowles (1894) and Sprague (1926). Grading of systolic murmurs was introduced by Samuel Levine in 1933. The acoustic principles of cardiovascular sound became better understood through the work of Rappaport and Sprague (1940s), and correlations were made with phonocardiography and cardiac catheterization by Paul Wood, Aubrey...
Leatham, Samuel Levine, and others between 1950 and 1975. In 1961, physiologist Robert Rushmer proposed the acceleration-deceleration theory that remains the concept of the generation of normal and abnormal heart sounds. Auscultation continues to be valuable although less relied on today as imaging tools such as the cardiac echocardiogram make visualization of cardiac structures straightforward, reproducible, and reliable.

TECHNOLOGY AND THE HEART

■ THE ELECTROCARDIOGRAM

In 1856, von Köllicker and Müller demonstrated that the heart also produced electricity. Augustus Waller, with a capillary electrometer device (1887), detected cardiac electricity from the limbs, a crude recording that he called an “electrogram.” Willem Einthoven, a physiologist in Utrecht, devised a more sensitive string galvanometer (1902), for which he received the Nobel Prize, and the modern electrocardiogram was born. Initially weighing 600 lb and requiring five people to operate, the 3-lead electrocardiograph would eventually become portable, 12 leads, routine, and capable of providing both static and continuous recordings of cardiac rhythm (Table 1–1).

Nineteenth-century researchers debated whether the heartbeat was stimulated by the heart muscle or was caused by external nervous or local ganglionic control—the myogenic versus the neurogenic theory. The answer was finally provided by the anatomic discovery and descriptions of the electrical system of the heart: the Purkinje fibers (1839), bundle of His (1893), bundle branches (1904), atrioventricular node (1906), and sinus node (1907). With the electrocardiogram, the activation and sequence of stimulation of the human heart could now be measured, and the anatomic basis for the conduction system confirmed. Thomas Lewis in London was the first to realize its great potential, beginning in 1909, and his books on disorders of the heartbeat became essential for aspiring electrocardiographers. Disorders of the heartbeat and abnormalities in the activation of the human heart, heretofore unknown or inferred from pulse tracings or experimental observations, became new clinical currency; palpitations became premature atrial or ventricular beats, and tachycardias and atrioventricular block could be understood. When electrocardiography was added to the chest x-ray and cardiac fluoroscopy in the early 20th century, clinical cardiology became a field of its own, inextricably linked to technology, a trend that continues in the 21st century. Those who interpreted the complicated tracings, known as cardiologists, became practitioners of this new specialty. By the 1930s, the electrocardiograph had become 12 leads and a necessary confirmation for myocardial ischemia or infarction. When electrocardiography was combined with the Master “two-step” exercise test (1940s), bicycle and treadmill stress testing (1960s), and nuclear and echocardiography imaging (1970s), a superior diagnostic approach to patients with chest pain became available. Continuous bedside monitoring (Paul Zoll, 1956) and the ambulatory detection of arrhythmias (Paul Zoll, 1956) became commonplace in the 1960s; and implanted pacemakers eventually became a marvel of reliability, complexity, and durability. Progressive advances include transvenous leads (1965), lithium iodine batteries (1972), multiprogrammability (1972), dual-chamber pacing (1980), rate adaptive modes, and antiarrhythmia programs. Biventricular pacing (1998) for patients with left ventricular dysfunction coupled with defibrillation capability has improved the quality of life and reduced mortality among some groups of patients with systolic heart failure. Electrophysiologic testing in humans began as an offshoot of basic catheterization laboratory investigations in the early pacemaker era. Intracardiac potentials were first measured in 1945. Catheter techniques were used to localize the His bundle (Scherlag and Damato, 1967) and to identify accessory pathways (Jackman, 1983). Programmed electrical stimulation of the heart was introduced to localize, provoke, and terminate arrhythmias (Durrer, Wellens, and Counell, 1967). Mapping techniques, applied to the surface of the heart for the localization and resection of accessory pathways (1968) and the surgical ablation of ventricular arrhythmias (1974) and atrial fibrillation (1991), became an essential method of investigation. As catheter methods of ablation improved, first coupled with intracardiac high-energy shock of the atrioventricular node (1982) and then with radiofrequency current (1987), ablation moved from the surgery suite into the laboratory setting, populated by a new subspecialty group—the electrophysiologists. Catheter ablation of atrioventricular nodal reentry was the next great success story. Atrial flutter and fibrillation and ventricular tachycardia are the newest targets for catheter ablation as the understanding of arrhythmias evolves through the use of more sophisticated intracardiac electrocardiograms coupled with a more detailed correlation with anatomy using magnetic resonance imaging (MRI) and computed tomography (CT) imaging to help guide procedures. Through an understanding of the mechanisms of arrhythmias and the identification of genes encoding cardiac ion channels—especially the long-QT and Brugada syndromes— electrocardiography has reemerged as a critical diagnostic and investigative tool.

■ THE CARDIAC CATHETER

If the ability to measure cardiac rhythm using the electrocardiograph was a touchstone for the identification of the cardiologist at the dawn of the 20th century, it was the ability to invasively measure cardiac pressures and oxygen saturation as well as the imaging of cardiac structures using the cardiac catheter that marked the transition to the modern definition of the cardiovascular specialist. Many of the fundamentals of modern cardiovascular instrumentation and physiology originated in France in the mid-19th century. Claude Bernard in 1844 was the first to insert a catheter into the heart of animals to measure temperature and pressure. In the 1860s, Etienne Jules Marey combined the kymographic instrumentation created by Ludwig in Leipzig in 1847 with an air-filled manometer for the graphic registration of biological phenomena. Marey’s pulse writer—the sphygmograph—was used for recording the external pulsation of the heart and arteries and was a prototype for noninvasive devices in cardiology. In the early 1860s, Auguste Chauveau, a veterinary physiologist, and Marey collaborated to develop a system of devices called sounds, forerunners of the modern cardiac catheter, which they used to catheterize the right heart and left ventricle of the horse. They recorded values of intracardiac pressure with superb tracings and correlated the intracardiac events with precision to show the relation of atrial and ventricular systole to the apex impulse. In 1870, Adolph Fick provided his oximetric formula to measure cardiac output.
### TABLE 1–1. Selected Advances in Cardiac Diagnosis and Technology

<table>
<thead>
<tr>
<th>ANCIENT TIMES</th>
<th>1600-1979</th>
</tr>
</thead>
<tbody>
<tr>
<td>General inspection</td>
<td>Computed electrocardiography (1961)</td>
</tr>
<tr>
<td>Palpation of the pulse (Egypt, China, India)</td>
<td>Ambulatory monitoring (1961)</td>
</tr>
<tr>
<td>18TH CENTURY</td>
<td>Creatine phosphokinase (1965)</td>
</tr>
<tr>
<td>Physician’s 1-min pulse watch (1707)</td>
<td>His bundle recording (1967)</td>
</tr>
<tr>
<td>Percussion of the chest (1761)</td>
<td>Transfemoral catheterization (1967)</td>
</tr>
<tr>
<td>19TH CENTURY</td>
<td>Contrast echocardiography (1968)</td>
</tr>
<tr>
<td>Stethoscopic auscultation of the heart (1816)</td>
<td>Swan–Ganz flotation catheter (1970)</td>
</tr>
<tr>
<td>Pneumograph (1826)</td>
<td>Digoxin level (1971)</td>
</tr>
<tr>
<td>Kymographic recording of pulses (1847)</td>
<td>Computed tomographic scanning (1971)</td>
</tr>
<tr>
<td>Sphygmograph for blood pressure measurement (1855, 1863)</td>
<td>Electrophysiologic testing (1972)</td>
</tr>
<tr>
<td>Polygraphic recording of pulses (1883)</td>
<td>Nuclear stress cardiology (1973)</td>
</tr>
<tr>
<td>Fluoroscopy (1896)</td>
<td>Doppler echocardiography (1975)</td>
</tr>
<tr>
<td>20TH CENTURY</td>
<td>Positron emission tomography (1979)</td>
</tr>
<tr>
<td>1900-1929</td>
<td>Stress echocardiography (1979)</td>
</tr>
<tr>
<td>Electrocardiogram (1902)</td>
<td>Ultrafast computed tomography (1979, 1990)</td>
</tr>
<tr>
<td>Auscultation of blood pressure (1905)</td>
<td>1980-1999</td>
</tr>
<tr>
<td>Phonocardiogram (1907)</td>
<td>Sign-al-averaged electrocardiography (1981)</td>
</tr>
<tr>
<td>Electrocardiography for myocardial infarction (1920)</td>
<td>Magnetic resonance imaging of the heart (1984)</td>
</tr>
<tr>
<td>Viscocardiography (1920)</td>
<td>ST-segment monitoring (1984)</td>
</tr>
<tr>
<td>Portable electrocardiogram (1928)</td>
<td>Transesophageal echocardiography (1985)</td>
</tr>
<tr>
<td>First cardiac catheterization (1929)</td>
<td>Dobutamine stress echocardiography (1986)</td>
</tr>
<tr>
<td>Bedside measurement of venous pressure (1930)</td>
<td>Heart rate variability (1973, 1987)</td>
</tr>
<tr>
<td>Cardiac output measurement (1870, 1930)</td>
<td>Electron beam tomography for coronary calcium (1990)</td>
</tr>
<tr>
<td>Circulation time (1931)</td>
<td>Troponin I (1992)</td>
</tr>
<tr>
<td>Precordial electrocardiography (1932)</td>
<td>B-type natriuretic peptide (1994)</td>
</tr>
<tr>
<td>Unipolar electrocardiography leads (1932)</td>
<td>Single-photon emission computed tomography (1990s)</td>
</tr>
<tr>
<td>Sedimentation rate for myocardial infarction (1933)</td>
<td>Implanted loop recorder (1999)</td>
</tr>
<tr>
<td>Development of cardiac catheterization (1941)</td>
<td>21ST CENTURY</td>
</tr>
<tr>
<td>Master “two-step” exercise test (1942)</td>
<td>64-slice computed tomography scanning (2005)</td>
</tr>
<tr>
<td>Left heart catheterization (1950)</td>
<td>Optical coherence tomography imaging (2006)</td>
</tr>
<tr>
<td>Image intensification (1953)</td>
<td>Fractional flow reserve invasive measurements (2007)</td>
</tr>
<tr>
<td>Serum glutamic oxaloacetic transaminase (1954)</td>
<td>Smartphone health applications (2012)</td>
</tr>
<tr>
<td>Cardiac monitoring (1956)</td>
<td>Fractional flow reserve noninvasive measurements (2014)</td>
</tr>
</tbody>
</table>
Cardiac catheterization in humans was thought an inconceivable risk until Werner Forssmann, a 29-year-old surgical resident in Germany, performed a self-catheterization in 1929.1,2 Interested in discovering a method of injecting adrenaline to treat cardiac arrest, Forssmann passed a ureteral catheter into his antecubital vein and confirmed its right atrial position using x-ray. The next year he attempted to image his heart using an iodide injection. However, he was reprimanded by superiors and did not experiment further. Catheterization began in earnest in the early 1940s in New York and London. André Cournand and Dickinson Richards at Bellevue, interested in respiratory physiology, developed and demonstrated the safety of complete right heart catheterization, for which they shared the Nobel Prize with Forssmann in 1956.3,4

The cardiac catheter was viewed initially as an instrument to measure pressure and cardiac output, sample blood contents, or deliver contrast agents for cardiovascular angiography. Brannon and Warren in Atlanta were the first to apply the catheter to diagnose heart disease—an atrial septal defect—in 1945. It was the impetus of cardiac surgery requiring an accurate diagnosis, initially for congenital heart and rheumatic mitral disease, that brought cardiac catheterization out of the physiology laboratory and to the forefront of clinical cardiology in the 1950s. Improved catheters and pressure manometers, automatic film changers, and the introduction of retrograde left heart catheterization by Henry Zimmerman (1950) and a percutaneous approach by Sven Seldinger (1953) advanced the technique, accompanying heart surgery into the era of valve replacement in the 1960s. Mason Sones’s accidental injection of contrast directly into a right coronary artery (1958) was a serendipitous leap forward, demonstrating that the epicardial coronary arteries could be safely visualized using percutaneous techniques. The Judkin transfemoral approach (1967) simplified selective coronary catheterization. Visualization of the coronary circulation ultimately led to the introduction of coronary bypass surgery by René Favaloro (1967) and percutaneous transluminal coronary angioplasty (PTCA) by Andreas Grünzig (1977).5,6 Since then, the versatile cardiac catheter has continued to evolve, carrying delivery systems or instruments ranging from ultrasound, balloons, and stents to defibrillators (Table 1–1; see also Table 1–1). Recent advances in catheter delivery technologies now allow percutaneous replacement of the aortic valve and repair of a regurgitant mitral valve.7 The modern descendant of Forssmann and others is now an endovascular specialist, capable of both diagnosing and treating diseases of cardiac structure and function as well as diseases of the peripheral arterial and venous circulations.8

# IMAGING OF THE HEART

## Radiography

Modern imaging technology began with Konrad Roentgen’s discovery of x-rays in 1895, for which he was awarded the Nobel Prize in Physics in 1901.9,10 Within a year, fluorescent screens were available to view cardiac pulsations. Contrast agents incorporating sodium iodide were necessary to visualize the organ cavities. Moniz in Lisbon (1931) and Castellanos in Cuba (1937) were the first to image the interior of the heart with intravenous angiograms.2 In the mid-20th century, electronic x-ray technology with the image intensifier allowed enhanced viewing of dynamic events in real time (see Table 1–1). Angiography became the focal point of cardiovascular imaging for several decades after the mid-20th century, vital to the diagnosis and management of coronary disease during the 1960s, and it continues to play a central role as the dominant imaging technique for the diagnosis and treatment of coronary and vascular obstructions.

## Nuclear Cardiology

Nuclear cardiology began with Herrmann Blumgart, who injected radon to measure the circulation time in 1927; followed by G. Liljestrand, who determined normal blood volume in 1939; and Myron Prinzmetal, who monitored the transit of radiolabeled albumin through the heart in 1948.20,21 Following World War II, radioactive isotopes and scintillation cameras became available for imaging purposes. Hal Anger’s gamma camera, a key development introduced in 1952, provided a high-resolution scanning capability that could visualize the cardiac chambers and assess function and shunting without moving the patient. Electrocardiographic gating, starting in the early 1970s, greatly improved the analysis of wall motion and ejection fraction, as did single-photon emission computed tomography (SPECT) in the 1990s. Nuclear stress testing for ischemia was introduced by Zaret and Strauss in 1973 using potassium 43 as the tracer. Redistribution studies, taking advantage of the properties of thallium 201 and technetium 99m, have improved the performance of the test, and pharmacologic stress testing has expanded their use.30,31 Advances combining positron emission tomography (PET) or SPECT scanning with CT allow the integration of knowledge of anatomy with cardiac function. Imaging of “vulnerable” atherosclerotic plaque that would allow detection of patients at risk for acute ischemic events remains a laudable but elusive diagnostic goal.32

## Echocardiography

Ultrasound imaging dates back to the production of sound waves from piezoelectric crystals in 1880 and the military use of sonar for the detection of reflected sound waves during World War II.33 Cardiac ultrasound was introduced in Sweden by Inge Edler and Helmuth Hertz, who detected the anterior mitral leaflet with postmortem correlation—an ice pick through the chest into the mitral leaflet (1954). Starting in the mid-1960s with the detection of pericardial effusion and left ventricular size, M-mode echocardiography became a powerful clinical technique developed by Harvey Feigenbaum, who taught the first generation of echocardiographers. Contrast echocardiography (1969), two-dimensional echocardiography (1974), pulsed Doppler hemodynamics (1975), stress echocardiography (1979), Doppler color-flow (1982), and transesophageal imaging (1985) have added to its enormous success. Intraoperative transesophageal monitoring and the intrauterine diagnosis of congenital heart disease have become possible. Additions include the assessment of diastolic function along with tissue strain rate and three-dimensional capabilities. Digital recording has significantly transformed the acquisition, storage, and interpretation of studies. Echocardiography has safely and brilliantly illuminated the heart and its function, becoming the main imaging tool of choice given its ready availability, its ease of use, and extensive investigations supporting its use as a diagnostic tool.34,35,36,37,38,39 Adding to the attractiveness of echocardiography as a mainstay among the cardiologist’s tools are smaller, pocket-sized devices that bring the technology to the bedside and the ability of smartphone technology to allow immediate sharing of high-quality images, thus speeding diagnosis and clinical decision making.33

## Computed Tomography and Magnetic Resonance Imaging

The three decades following the introduction of the gamma camera and ultrasound brought transformative expansion to the medical imaging field, including CT (1963–1971), SPECT (1963–1981), PET (1975–1987), and MRI (1972–1981), each delivering its own exciting ability to transform field, including CT (1963–1971), SPECT (1963–1981), PET (1975–1987), and MRI (1972–1981), each delivering its own exciting ability to transform field, including CT (1963–1971), SPECT (1963–1981), PET (1975–1987), and MRI (1972–1981), each delivering its own exciting ability to transform field, including CT (1963–1971), SPECT (1963–1981), PET (1975–1987), and MRI (1972–1981), each delivering its own exciting ability to transform the acquisition, storage, and interpretation of studies. Echocardiography has safely and brilliantly illuminated the heart and its function, becoming the main imaging tool of choice given its ready availability, its ease of use, and extensive investigations supporting its use as a diagnostic tool.34,35,36,37,38,39 Adding to the attractiveness of echocardiography as a mainstay among the cardiologist’s tools are smaller, pocket-sized devices that bring the technology to the bedside and the ability of smartphone technology to allow immediate sharing of high-quality images, thus speeding diagnosis and clinical decision making.33
### TABLE 1–2. Selected Advances in Medical Therapy: 1900 to the Present

<table>
<thead>
<tr>
<th>Available in 1900 (alphabetically)</th>
<th>Streptokinase for myocardial infarction (1958)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>Guanethidine (1959)</td>
</tr>
<tr>
<td>Amyl nitrite (1867)</td>
<td>1960–1969</td>
</tr>
<tr>
<td>Atropine (1833, 1867)</td>
<td>Closed chest cardiac massage (1960)</td>
</tr>
<tr>
<td>Caffeine (1879)</td>
<td>Cardioversion of ventricular tachycardia (1960)</td>
</tr>
<tr>
<td>Chloroform (1831)</td>
<td>Amiodarone (1961)</td>
</tr>
<tr>
<td>Diet</td>
<td>Coronary care units (1961)</td>
</tr>
<tr>
<td>Digitals (1785)</td>
<td>Beta-blockers (1962)</td>
</tr>
<tr>
<td>Ether (1842)</td>
<td>Synchronized cardioversion (1962)</td>
</tr>
<tr>
<td>Exercise</td>
<td>Disopyramide (1963)</td>
</tr>
<tr>
<td>Leeches</td>
<td>Lidocaine (1963)</td>
</tr>
<tr>
<td>Morphine (1821)</td>
<td>Furosemide (1964)</td>
</tr>
<tr>
<td>Nitroglycerine (1879)</td>
<td>Balloon atrial septostomy (Rashkind procedure, 1966)</td>
</tr>
<tr>
<td>Quinine (1745)</td>
<td>Programmed electrophysiologic stimulation (1967)</td>
</tr>
<tr>
<td>Salicylic acid (1876)</td>
<td>Mobile intensive care unit (1967)</td>
</tr>
<tr>
<td>Southey trocars</td>
<td>Bretylium tosylate (1968)</td>
</tr>
<tr>
<td>Spa therapy</td>
<td>Outpatient cardiac rehabilitation (1968)</td>
</tr>
<tr>
<td>Squill (17th century)</td>
<td>1970–1979</td>
</tr>
<tr>
<td>Theobromine (1879)</td>
<td>Calcium channel blocking agents (1970)</td>
</tr>
<tr>
<td>Venesection</td>
<td>Vasodilator therapy (1971)</td>
</tr>
<tr>
<td>Veratrum viride (1859)</td>
<td>Stenting of patent ductus arteriosus (1971)</td>
</tr>
<tr>
<td><strong>1900–1949</strong></td>
<td>Dopamine (1972)</td>
</tr>
<tr>
<td>Adrenaline (1900)</td>
<td>Intravenous verapamil (1972)</td>
</tr>
<tr>
<td>Oxygen (1908)</td>
<td>Nitroprusside (1974)</td>
</tr>
<tr>
<td>Quinidine (1914)</td>
<td>Beta-blockers for heart failure (1975)</td>
</tr>
<tr>
<td>Mercury diuretics (1920)</td>
<td>Debutamine (1975)</td>
</tr>
<tr>
<td>Magnesium (1935)</td>
<td>Coronary angioplasty (1977)</td>
</tr>
<tr>
<td>Penicillin (1940)</td>
<td>Intracoronary thrombolysis (streptokinase) (1979)</td>
</tr>
<tr>
<td>Rice diet (Kempner, 1944)</td>
<td>Phosphodiesterase inhibitors (1980)</td>
</tr>
<tr>
<td>Cation exchange resins (1946)</td>
<td>Propafenone (1980)</td>
</tr>
<tr>
<td>Reserpine (1949)</td>
<td>Flecaïnide (1982)</td>
</tr>
<tr>
<td>Hydralazine (1951)</td>
<td>Low-molecular-weight heparin (1986)</td>
</tr>
<tr>
<td>Procainamide (1951)</td>
<td>HMG-CoA reductase inhibitor (1986)</td>
</tr>
<tr>
<td>Ambulation post–myocardial infarction (1952)</td>
<td>Intravenous thrombolysis (1987)</td>
</tr>
<tr>
<td>External cardiac pacing (1952)</td>
<td>Aspirin for primary prevention (1989)</td>
</tr>
<tr>
<td>Alpha methyl dopa (1955)</td>
<td>1990–1999</td>
</tr>
<tr>
<td>Chlorothiazide (1957)</td>
<td></td>
</tr>
</tbody>
</table>
coronary atherosclerosis. The multislice CT angiogram (2005) provides detailed coronary anatomy along with ventricular wall motion. With the possibility of perfusion scanning being added to CT capabilities, CT is competing with coronary angiography and nuclear imaging as the initial imaging study for patients with suspected coronary artery disease, although there are concerns about the cumulative effects of radiation exposure that accompanies cardiac imaging.33

Cardiac MRI has emerged as a powerful tool to visualize cardiac structures with clarity and precision. For example, MRI can be useful in the very accurate quantification of myocardial infarct size that correlates well with pathologic examination.34 Because MRI does not involve ionizing radiation, it has emerged as a very helpful imaging modality in the sequential care of children and adults with complex congenital heart disease, including to follow up and plan for percutaneous and surgical repairs. MRI techniques can be used for perfusion scanning using vasodilating stress agents.35,36 Finally, magnetic resonance angiography, or MRA, allows contrast-enhanced imaging of vascular structures that often can provide the endovascular specialist with a “roadmap” for therapeutic interventions. As with other imaging modalities, collaborations among academics, clinicians, and industry, leveraging the advantage of the information processing capabilities of the computer, have provided the basis for each technological advance.

## CORONARY ARTERY DISEASE

### DIAGNOSIS OF CORONARY ARTERY DISEASE AND ITS ETIOLOGY

On July 21, 1768, William Heberden presented “Some Account of a Disorder of the Breast” to the Royal College of Physicians, London: “But there is a disorder of the breast marked with strong and peculiar symptoms, considerable for the kind of danger belonging to it, and not extremely rare. The seat of it, and sense of strangling and anxiety with which it is attended, may make it not improperly be called angina pectoris.” Heberden appropriated the term angina from the Latin word for strangling. His classic account marks the beginning of our appreciation of coronary artery disease and myocardial ischemia. Edward Jenner and Caleb Parry were the first to suspect a coronary etiology, which Parry published in 1799. Allan Burns, in Scotland, likened the pain of angina pectoris to the discomfort brought about by walking with a tight ligature placed on a limb (1809), a prescient concept that remains relevant today. Nevertheless, a coronary cause of angina pectoris was not readily accepted until the late 19th century. The term arteriosclerosis was coined by Johann Lobstein (1833). Key pathologic observations were made by Rudolf Virchow, who established the importance of thrombosis of arteries as a cause of disease (1846); Richard Quain, who associated the fatty degeneration of cardiac muscle with coronary obstruction (1850); Karl Weigert, who described the pathology of myocardial infarction and remarked on the importance of collateral vessels (1880); and Karl Huber, who suggested that atheroma could cut off the blood supply and lead to myocardial fibrosis (1882). Adam Hammer was the first to report the premortem diagnosis of myocardial infarction (1878).

By the late 19th century, angina pectoris was linked with coronary artery disease, although there was confusion about the association between angina pectoris and myocardial infarction. Coronary disease was thought to be uncommon at that time. Julius Cohnheim taught that coronary arteries were end arteries, noting that experimental ligation of a coronary artery resulted in ventricular fibrillation (1881). In 1901, Osler called the anterior branch the “artery of sudden death,” later stating that “the tragedies of life are largely arterial.” The concept that coronary thrombosis was always fatal was finally dispelled by James Herrick (1912). He concluded “there is no inherent reason why the stoppage of a large branch of a coronary artery, or even of a main trunk, must of necessity cause sudden death.” Herrick was the first to grasp the variable course of myocardial infarction. The three-lead electrocardiogram was used by Herrick and Smith to diagnose experimental infarction (1918) and in humans by Pardee (1920). Precordial leads, introduced by Frank Wilson in the 1930s, furthered the diagnosis. Between 1928 and 1950, large series of patients—analyzed by John Parkinson and Evan Bedford in London, Samuel Levine and Paul Dudley White in Boston, Charles Friedberg in New York, and others—provided a broad understanding of the clinical, electrocardiographic, and laboratory findings of myocardial infarction as well as its prognosis and autopsy correlations. By the 1930s, myocardial infarction was a familiar diagnosis believed to be increasing in frequency. This change in epidemiology tracked the urbanization of American society, the reduction in deaths from infectious diseases (resulting from both public health improvements as well as the discovery of antibiotics) and, probably most contributory, increasing tobacco use among adults.

The clinical-pathologic correlations of atherosclerosis and thrombosis with infarction were greatly strengthened by the 1940 postmortem

---

<table>
<thead>
<tr>
<th>TABLE 1–2. Selected Advances in Medical Therapy: 1900 to the Present (Continued)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiotensin II receptor blocking agents (1992)</td>
<td>Ticagrelor (2011)</td>
</tr>
<tr>
<td>2000–2009</td>
<td></td>
</tr>
</tbody>
</table>
coronary injection studies of Blumgart, Schlesinger, and Davis. Autoradiographic postmortem studies by Fulton in Glasgow (1976) and DeWood’s seminal coronary arteriographic studies in patients with acute myocardial infarction (1980) finally proved that a thrombus was the causative event leading to acute coronary obstruction. The “vulnerable plaque” hypothesis has gained widespread support as the cause of acute coronary disease and sudden death. Inflammation, ignited by risk factors such as smoking, hypertension, hyperlipidemia, and diabetes, underlies “atherothrombosis,” and plaque disruption (rupture, fissure, erosion followed by repair) is now realized to be a complex interplay of events but one largely driven by inflammatory cells such as monocytes and macrophages and the response to vascular injury of the hemostatic system.10,11

### TREATMENT OF ANGINA PECTORIS

Treatment of angina pectoris began with amyl nitrite used by Lauder Brunton (1867) and nitroglycerine by William Murrell (1879). Before 1970, xanthine derivatives, sedatives, opiates, diet, prolonged rest, alcohol, long-acting nitrates, paravertebral alcohol injections, dorsal sympathectomy, induction of myxedema, instillation of t alc or bone dust into the pericardium, denervation of the heart, radiation to the anterior chest, and carotid sinus pacing enjoyed temporary support. β-Adrenergic blockade, beginning in the early 1970s, greatly improved the management of angina; clinical trials in the 1980s showed that the risk of myocardial infarction among certain groups of patients (such as those with a first myocardial infarction) could be reduced by the use of β-blockade. Calcium channel blockers and nitroglycerine administered by paste and intravenously were introduced in the late 1970s (Table 1–3). PTCA using balloon inflations for alleviating angina was the concept of Grünzig, working in Zü rich (1977). He was influenced by Charles Dotter’s 1964 demonstration that peripheral atherosclerosis was malleable. Balloon angioplasty was improved by bare metal stenting of coronary arteries (1986), primary angioplasty for acute infarction (1988), brachytherapy (2000), and eventually drug-eluting stents (2001).12,14 Restenosis with subsequent need for repeat revascularization, the Achilles heel of balloon angioplasty, has fallen from a range of 30% to 40% to approximately 5% with the latest generation of drug-eluting stents. Technology advances with both devices and adjunctive pharmacology has allowed percutaneous coronary intervention (PCI) to be applied to more complicated patients (eg, older patients with more comorbidities) and more complex coronary anatomy (eg, left main and multivessel coronary artery disease). Challenges remain with stent thrombosis, bifurcation disease, saphenous vein graft disease, and chronic total coronary occlusions. Patients with advanced coronary artery disease not thought to be amenable to current revascularization techniques represent an important and growing group for whom investigation with novel approaches such as cellular therapies holds promise.15

### TREATMENT OF ACUTE CORONARY SYNDROMES

Strict bedrest for 6 to 8 weeks was rigidly advised for heart attacks until 1952, when Levine and Lown suggested an “armchair” approach was better. Anticoagulation, strongly recommended by Wood and others for myocardial infarction in the 1950s, became controversial in the 1960s. Before the defibrillator and coronary care units, the in-hospital mortality associated with acute myocardial infarction was approximately 30%. With the development of the defibrillator by William Kouwenhoven, Claude Beck and Paul Zoll were able to prove that rescue of cardiac arrest victims was possible. Beck’s concept that “the heart is too good to die” instilled optimism into the care of coronary patients and aggressiveness into their providers. Myocardial infarction was no longer a disease to be watched but rather one that might benefit from aggressive therapeutic interventions. Zoll reported closed chest defibrillation in 1956 and cardioversion of ventricular tachycardia in 1960. The monitoring of patients in close proximity to skilled nursing personnel who could perform cardiopulmonary resuscitation was a logical next step suggested by Desmond Julian in 1961. Since then, coronary care has gone through a series of recognizable phases: first, cardiac resuscitation and the essential role of the nurse; second, prevention and treatment of life-threatening arrhythmias; third, hemodynamic catheter monitoring (the pulmonary artery or Swan-Ganz catheter)16 and treatment of pump failure; fourth, reduction of infarct size—first with adjunctive medical therapies such as β-blockers and then with reperfusion therapies, including fibrinolytic therapy (1987) and primary angioplasty; and, finally, the current phase devoted to developing and implementing coordinated systems with multidisciplinary teams to efficiently deliver complex cardiac care, including acute coronary care with invasive management techniques and advanced heart failure with mechanical ventricular support devices.

Fibrinolytic therapy for acute myocardial infarction, using small doses of intravenous streptokinase, was first tried in 1958 by Fletcher and Sherry and given as an intracoronary infusion by Boucek and Murphy in 1960 and Chazov in 1976.17 The rationale for thrombolysis derives from a 1977 report by Reimer and colleagues describing the “wavefront” phenomenon of myocardial infarction and stating that necrosis from infarction progresses over a period of 3 to 6 hours, suggesting that early restoration of epicardial coronary blood flow can salvage threatened myocardium and limit infarct size. Its current use, emphasizing that “time is muscle,” began with intracoronary infusion of streptokinase in 1979 by Rentrop and was followed by intravenous streptokinase (1983) and intravenous tissue plasminogen activator in 1987. Small clinical trials first suggested that primary angioplasty was superior to medical reperfusion with fibrinolysis, and aggregated analyses of these trials solidified the role of primary PCI in the initial care of the myocardial infarction patient.17

There is no question that the rapid delivery of reperfusion therapy improves coronary blood flow, reduces infarct size, and improves mortality. The challenges now center around improving early detection of symptoms and entry into the emergency medical system, rapid diagnosis and triage, transfer to facilities offering the most appropriate level of acute cardiac care, and rapid administration of reperfusion therapy by experienced providers.17,18 Additionally, the advanced elderly (> 75 years) present unique challenges in myocardial infarction management that require further investigation. Cardiogenic shock remains a major challenge for the modern cardiac care unit, with this cohort of myocardial infarction patients accounting for the majority of short-term mortality. New insights into shock that consider it as an inflammatory disorder open up avenues of needed research to further decrease acute myocardial infarction mortality.19 Important adjuncts to reperfusion therapy include β-blockers, angiotensin-converting enzyme (ACE) inhibitors, and antithrombotic therapy, including antiplatelet and anticoagulant therapies.19,20 Insights gained from hypothermia survivor observations have led to the concept of therapeutic hypothermia to improve cardiac survival among those who have sudden death as a complication of myocardial infarction. Earlier detection of patients at risk for sudden cardiac death is one of the next frontiers in acute myocardial infarction research.17

### PREVENTION OF CORONARY ARTERY DISEASE

Cardiovascular epidemiologic studies, advocated by Paul Dudley White, began in earnest with the National Institutes of Health (NIH)-sponsored
<table>
<thead>
<tr>
<th>TABLE 1–3. Selected Advances in Cardiovascular Surgery and Intervention</th>
</tr>
</thead>
</table>

**19TH CENTURY**
- Drainage of pericardial effusion (1810)
- Introduction of ether anesthesia (1842)
- Removal of foreign body from heart (1873)
- Surgical closure of stab wound of heart (1896)

**20TH CENTURY**

**1900-1925**
- End-to-end arterial anastomosis (1902)
- Animal heart transplantation (1905)
- Arterial patch graft (1910)
- Coronary artery bypass in animal (1910)
- Insufflation endotracheal anesthesia (1910)
- Attempted external dilatation of aortic stenosis (1912)
- Pericardial resection for constriction (1913)
- Sympathectomy (1917)
- Mitral stenosis valvulotomy (1923)
- Pulmonary embolectomy (1924)
- Lumbar sympathectomy (1925)
- Mitral stenosis dilatation by finger (1925)

**1926-1950**
- Cardio-omentopexy (1930s)
- Thyroidectomy for angina pectoris (1933)
- Ligation of patent ductus arteriosus (1938)
- Coarctation repair (1944)
- Subclavian artery to pulmonary artery anastomosis for tetralogy of Fallot (Blalock-Taussig shunt, 1944)
- Heart-lung transplant (World War II)
- Side-to-side anastomosis of aorta to pulmonary artery for tetralogy of Fallot (Potts procedure, 1946)
- Valvotomy for pulmonic stenosis (Brock procedure, 1947)
- Closed mitral commissurotomy (1948)
- Resection of infundibulum of right ventricle (1948)
- Atroventricular synchronous pacemaker (1962)
- Hypothermia (1950)

**1951-1975**
- Closure atrial septal defect (1950s)
- First prosthetic ball valve—intact aorta for aortic regurgitation (1952)
- Resection abdominal aortic aneurysm (1952)
- Extracorporeal circulation (1953)
- Pulmonary artery banding (1953)
- Aortic dissection repair (1954)
- Carotid endarterectomy (1954)
- Closure ventricular septal defect (1954)
- Cross-circulation of oxygenated blood (1954)
- Tetralogy of Fallot repair (1954)
- Potassium cardioplegia (1955)
- Aortic valvotomy (1956, 1958)
- Transection of ventricular septum for idiopathic hypertrophic subaortic stenosis (1957)
- Resection ventricular aneurysm (1958)
- Superior vena cava to pulmonary artery shunt (Glenn procedure, 1959)
- Transposition of great vessels repair (Senning procedure, 1959)
- Aortic ball and cage valve (1960)
- Implantable pacemaker (1960)
- Mitral ball and cage valve replacement (1960)
- Excision of ventricular aneurysm (1961)
- Atroventricular synchronous pacemaker (1962)
- Homograft valve (1962)
- Intra-aortic balloon pump (1962)
- Arterial switch procedure for transposition of great vessels (1976)
- Stenting of patent ductus arteriosus (1971)
- Lithium battery pacemaker (1972)
- Cardiac transplantation (1967)
- Saphenous vein to coronary artery bypass (1968)
- Crus arteriosus repair (1968)
- Wolff-Parkinson-White surgery (1968)
- Extracardiac conduit (Rastelli procedure, 1969)
- Heart and lung transplant (1969)
- Tilted disk valve (1969)
- Bioprosthetic valve (1970)
- Connection of right atrial appendage to pulmonary artery for tricuspid atresia (Fontan procedure, 1970)
- Aortic valve replacement (1971)
- Mitral valve repair (1971)
- Stenting of patent ductus arteriosus (1971)
- Lithium battery pacemaker (1972)
- Porcine valve (1975)

**1976-1999**
- Arterial switch procedure for transposition of great vessels (1976)
- Tilted disk valve (1977)
- Bileaflet hinged valve (1977)
- Pneumatic valve (1980)
- Dual-chamber pacing (1980)
- Automatic implanted defibrillator (1980)

(continued)
TABLE 1–3. Selected Advances in Medical Therapy: 1900 to the Present (Continued)

<table>
<thead>
<tr>
<th>VALVULAR HEART DISEASE</th>
</tr>
</thead>
</table>

Framingham study (1948) and the work of Ancel Keys in Minnesota. These landmark studies emphasized prevention of coronary disease through recognition and treatment of risk factors. The metabolic syndrome, first described in 1983 and now an epidemic driven by visceral obesity, has risen to become a public health problem of global significance.\(^7,9\) The vascular protective and relaxing role of the endothelium, through its generation of nitric oxide, and the dangers of endothelial dysfunction were key basic science discoveries (1970s) for which the Nobel Prize was awarded in 1998.\(^8\) The hydroxyl methylglutaryl coenzyme A (HMG-CoA) reductase inhibitors (known widely as “statins”), isolated by Akira Endo in Japan (1976) and commercially available since 1986, have dramatically decreased mortality, heart attacks, and strokes among a broad spectrum of patients with or at risk of cardiovascular disease. With a continuing target of further decreasing low-density lipoprotein (LDL) levels, the proprotein convertase subtilisin kexin 9 inhibitors offer the ability to lower LDL to even lower levels. Whether this profound reduction in LDL translates into clinical benefit awaits the results of large ongoing clinical trials.\(^3,4\)

More recently, attention has turned to elevating high-density lipoprotein (HDL) levels to stabilize or reverse atheroma. However, no HDL-raising therapy to date has resulted in an improvement in clinical outcomes in large randomized trials. Diabetes has become a global problem with resultant increases in cardiac diseases, including among the young and in countries with emerging economies. Linked to obesity and sedentary lifestyles, its prevention and treatment threaten to consume huge portions of global health care spending. Managing this problem will be one of the key medical and scientific priorities of the next few decades.\(^5,6\)

Valvular pathology was described in the 17th and 18th centuries; however, Laennec was the first to describe audible heart murmurs, calling them “blowing, sawing, filing, and rasping.”\(^1\) Originally, he attributed the noise to actual valvular disease, but he later decided that they were caused by spasm or contraction of a cardiac chamber. James Hope in England was the first to classify valvular murmurs in A Treatise on the Diseases of the Heart and Great Vessels (1832).\(^2\) He interpreted physical findings in early physiologic terms and provided detailed pathologic correlations.\(^3\) Constriction of the mitral valve was recorded by John Mayow (1668) and Raymond VIEUSSENS (1715); the latter also recognized that it could cause pulmonary congestion.\(^4\) The presystolic murmur of mitral stenosis was described by Bertin (1824), timed as both early diastolic and presystolic by Williams (1835), and placed on firmer grounds by Fauvel (1843) and Gairdner (1861). Aortic stenosis was first described pathologically by Rivière (1663), and Laennec pointed out that the aortic valve was subject to ossification (1819).\(^5\) Corvisart showed an astute grasp of the natural history of aortic stenosis (1809) commenting:

*When it is considered how narrow the opening is, which these constrictions leave, it is difficult to conceive how such an organic derangement can continue for years. It is evident, if such an obstacle to the circulation were suddenly introduced into a healthy subject, death would immediately follow; but as these obstacles are slowly formed, the circulation is gradually impeded, and nature seems in some measure to be habituated to such a perversion of her laws.*

Early descriptions of aortic regurgitation were by William Cowper (1706) and Raymond VIEUSSENS (1715),\(^6\) whereas Giovanni Morgagni recognized the hemodynamic consequences of aortic regurgitation (1761). In 1832, Corrigan provided his classic description of the arterial pulse and murmur of aortic regurgitation. Flint added that the presystolic murmur was sometimes heard with severe aortic regurgitation (1862).\(^7\) The etiology of valvular disease in the 19th and first half of the 20th century revolved about the role of rheumatic fever. David Pitcairn was the first to suggest rheumatism of the heart (1788), and William Charles Wells described acute rheumatic fever with cardiac involvement in 1812.\(^8\) Jean-Baptiste Bouillaud established that acute articular rheumatism was associated with inflammation leading to valvular deformities (1836).\(^9\) Acceptance of the association between rheumatism—rheumatic fever—and subsequent valvular heart disease was gradually accepted. By the late 1980s, treatment of rheumatic episodes with salicylic acid had been introduced. Over time, the link between the throat, heart, and rheumatic fever was clarified; the role of *Streptococcus* was identified; and attention was paid to environmental factors—poverty, overcrowding, and malnutrition. Diagnostic criteria for acute rheumatic fever were established by T. Duckett Jones in 1944 with revisions through 1992. Antibiotic therapy has contributed to the great decrease in rheumatic fever in the Western world, but it should be noted that rheumatic heart disease remains a major global public health problem.\(^10\)
Beginning with cardiac catheterization in the 1950s and supplemented by echocardiographic imaging in the 1970s and now with MRI and CT scanning, the severity of valvular disease is readily analyzed and its progression followed. Our understanding of the etiology of valvular heart disease changed dramatically with the recognition of many nonrheumatic causes of valvular disease; especially the “floppy mitral valve” with prolapse by Reid and Barlow in the early 1960s. Since 1997, inflammation of the aortic valve, attributed to atherosclerotic risk factors, has been shown to play a central role in the development of adult aortic stenosis, although treatment with anti-inflammatory drugs such as the statins or other lipid-lowering therapies have not yet been shown to alter the course of the valvular disease.

Today, there is no “typical” patient with valvular heart disease; treatment involves medical, surgical, and interventional care, all guided by sophisticated imaging. The care of these patients is the purview of experts in the broader category of structural heart disease that includes valve disease as well as structural abnormalities such as septal defects and septal hypertrophy. The development of transcatheter aortic valve replacement, or TAVR, and its subsequent introduction into routine clinical practice has altered the approach to patients with aortic stenosis and opened avenues into considering other percutaneous approaches to valvular and structural heart disease.

CARDIOMYOPATHY

At mid-20th century, Henry A. Christian published Non-Valvular Heart Disease. He considered this to be the most frequent form of heart disease among individuals past middle age. At that time, acute or chronic myocarditis was thought to be the major cause; however, he considered the role of hypertension, ventricular hypertrophy and dilatation, heart failure without enlargement, and familial occurrence. Subsequent writers gradually shifted the emphasis from myocarditis to primary (idiopathic) myocardial disease.

The term cardiomyopathy, referring to the noncoronary cardiomyopathies, was introduced by Wallace Brigden in 1957. During this period, a dynamic form of subaortic stenosis was discovered and its hemodynamics investigated, and John Goodwin in London presented a new classification based on hypertrophy, dilatation, or restriction (1961). Myocardial biopsy, new imaging modalities, and biochemical and genetic studies have reshaped the understanding of cardiomyopathy along with more precise definition of the etiology of myocarditis. There is also a growing understanding of the contributory role of genetics in the development of the congenital/idiopathic cardiomyopathies.

CONGENITAL HEART DISEASE

Early textbooks in cardiology by Jean-Baptiste Senac (1749) and Allan Burns (1809) included comments on cardiac malformations. Cyanotic heart disease is mentioned; however, its mechanism was debated because some patients with septal defects had cyanosis although others did not. An early, comprehensive book devoted to cyanotic and acyanotic congenital heart disease, On Malformations of the Human Heart, was published in 1856 and 1866 by Thomas Bevill Peacock, a physician in London with a special interest in pathology. In his book, Peacock reviews the previous literature and provides detailed case studies, engravings of the pathology, personal insights, and an anatomic classification of more than 100 patients.

Following Peacock’s book, advances in congenital heart disease were limited primarily to pathologic descriptions and summaries until the seminal work of the pathologist Maude Abbott. Beginning in 1908, Abbott catalogued the pathology collection at the Montreal General Hospital, compiling 1000 cases that were fully analyzed in her 1936 classic, Atlas of Congenital Heart Disease. Her meticulous work provided a new classification correlating the history, examination, and postmortem findings with illustrations and became the foundation for the study of congenital heart disease. Maternal rubella studies (1940) brought attention to viral influences on cardiac development.

The pivotal breakthrough in thinking about congenital abnormalities came from Helen Taussig and Alfred Blalock at Johns Hopkins Hospital with their “blue baby operation.” Taussig had observed that patients with cyanotic heart disease worsened when their ductus arteriosus closed. She suggested creating an artificial ductus to improve oxygenation. Blalock, assisted by Vivian Thomas, successfully created a shunt from the subclavian to the pulmonary artery in November 1944. This innovative operation, in which a blue baby was dramatically changed to a pink one—the Blalock-Taussig shunt—was highly publicized, and other shunt operations soon followed (see Table 1–2). Taussig’s Congenital Malformations of the Heart, a 1947 compendium with schematics explaining the pathophysiology of the defect, became the ultimate authority on congenital heart disease. Studies in the 1950s correlated the clinical with the cardiac catheterization findings and led to a firmer physiologic basis for selecting patients who might benefit from the upcoming advances in congenital heart surgery. Natural history studies helped to clarify their prognosis.

In 1966, Rashkind introduced the balloon septostomy, a novel catheter therapeutic technique that bought time for severely cyanotic infants with transposition of the great arteries. In the 1980s, catheters were adapted to dilate stenotic aortic and pulmonic valves as well as aortic coarctation. Today, transcatheter closure of patent ductus arteriosus (1971), atrial septal defects (1976), and ventricular septal defects (1987) has become routine. Indomethacin therapy to enable closure of a patent ductus in the premature infant (1976) and prostaglandin infusion to maintain ductal patency (1981) profoundly changed the medical management of fragile newborns. Stents now help keep the ductus open as well as alleviate right ventricular obstruction in tetralogy of Fallot.

Until the 1970s, confirmation of a complex clinical diagnosis, mandatory for critical surgical decisions, required cardiac catheterization and angiography. In the late 1970s and 1980s, two-dimensional and color-flow Doppler echocardiography and later MRI became available to provide a quick diagnosis. With aggressive medical and catheter management, the approach to neonates, including intrauterine intervention, has radically changed. Improvements in operative techniques allowed innovative surgeons to operate earlier on smaller and sicker hearts while offering palliation or complete repair for congenital defects. With continued improvement in surgical techniques coupled with advances in postoperative intensive care, repair of previously lethal congenital abnormalities has now become possible. Adult congenital heart clinics have been an offshoot of the increased survival of children with congenital heart disease; there are now more adults than children with congenital heart disease.

AORTIC DISEASE

Aristotle (384-322 bc) named the great arterial vessel the aorta. Vesalius (1514-1564) is credited with the first description of an aneurysm of the abdominal and thoracic aorta (1555). Aneurysm (from the Greek word dilatation) of the aorta caught the attention of many early anatomists, especially Giovanni Maria Lancisi (1654-1720), whose 1728 book, De Moto Cordis et Aneurysmatibus, provided a definition and
classification, separated true from false aneurysms, discussed possible etiologies, and included case studies. Trauma and syphilis were particularly singled out as causes of aneurysms by Lancisi and his followers. Coarctation of the aorta (from the Latin coarctatus, meaning pressed together, contracted) was best described by M. Paris (1791).

Aortic dissection was not distinguished as a separate entity until The Seats and Causes of Diseases, published by Morgagni in 1761. He reported a 50-year-old woman who cried, "Oh!" and then died instantly. At autopsy, he "observed the blood had, by degrees, made itself a way through one of the intervals of this kind, and had come out under the external coat of the artery ... as a large kind of ecchymosis ... had burst through this external coat in one place, and had poured itself out within the pericardium." Laennec provided the term l’anevrisme disséquant (dissecting aneurysm) in 1826. Over the next century, the separation of a true aneurysm from a dissecting aneurysm, the pathogenesis from an initial transverse tear to a distal entry, the association of coarctation with a bicuspid aortic valve and hypertension, the significance of cystic medial necrosis, and the natural history of a large series of patients with dissection were recognized. More recently, there has been a greater recognition of heritable disorders of connective tissue and the vulnerability of the vascular system to risk factors and inherited disorders. Cardiovascular imaging has clarified the overlap of intramural hematoma, aortic dissection, and penetrating atherosclerotic ulcers. More advanced vascular imaging with MRI and CT that allow three-dimensional reconstruction of the aorta and great vessels has permitted increasingly complex surgical repair and reconstruction of disorders of the thoracic aorta and has paved the way for percutaneous endovascular approaches.88

BLOOD PRESSURE MEASUREMENT AND HYPERTENSION

Stephen Hales, an English country parson, reported in his Statical Essays (1733) that the arterial blood pressure of the cannulated artery of a recumbent horse rose more than 8 feet above the heart—the first true measurement of arterial pressure and the beginning of sphygmomentry.2,3,9 His pioneering efforts stood alone until 1828 when Jean Poiseuille introduced a mercury manometer device to measure blood pressure.101,105 Over the next 60 years, various sphygmomanometric methods were developed—notably by Ludwig (1847), Vierordt (1855), and Mary (1863) — to refine the measurement of the arterial pressure. An inflatable arm cuff coupled to the sphygmograph, a device small enough to allow measurement outside the laboratory, was invented by Riva-Rocci (1896), who also noted the “white-coat effect” on blood pressure.102 Nicolai Korotkoff, a Russian military surgeon, first auscultated brachial arterial sounds (1905), a discovery that marked the advent of modern blood pressure recording. This auscultatory approach eventually ensured its widespread use by the 1920s. In 1939, blood pressure recordings were standardized by committees of the American Heart Association (AHA) and the Cardiac Society of Great Britain and Ireland.

Richard Bright was the first to note the association among kidney disease, hypertrophy of the heart, dropsy (congestive failure), and hardening of the arteries (1827).31 In the 1870s, the studies of Frederick Mahomed in London established that elevated blood pressure could occur in the absence of nephritis and produce secondary kidney and arteriolar disease.32 Secondary causes of hypertension were discovered. Robert Tigerstedt in Stockholm discovered a pressor substance in the renal cortex, which he named renin in 1898; however, Goldblatt’s experiments, showing that renal artery stenosis induced ischemia and hypertension (1934), eventually led to the understanding of the renin, angiotensin, and aldosterone interaction by Pickering, Page, Braun-Menendez, Laragh, and others.103 Beginning in the late 19th century, vasomotor, neurohormonal, and baroreceptor reflexes as well as genetic determinants of blood pressure became known. The crucial role of sodium was further delineated by Guyton in the 1960s. Pickering and Platt debated whether or not there was a precise demarcation between normal and abnormal blood pressure in the late 1950s. In 1972, Pickering stated: "There is no dividing line. The relationship between arterial pressure and mortality is quantitative: the higher the pressure, the worse the prognosis."99 Subsequent studies have been supportive and the level where treatment should begin has been lowered, although optimal blood pressure across age groups has yet to be defined by appropriate clinical studies.

In 1913, Janeway showed that patients, once diagnosed with hypertensive heart disease and symptoms, lived an average of 4 to 5 years. However, the asymptomatic state of most patients with hypertension, the lack of effective treatment, and a prevalent view that lowering the blood pressure would be deleterious to the kidney and brain lulled most physicians into accepting the condition as being normally associated with aging. In the 1970s, reports from the Framingham Heart Study showed hypertension to be a major contributing cause to stroke, heart attack, and heart and kidney failure. Hypertension was labeled “the silent killer.” Other studies followed indicating that treatment of even mild hypertension could reduce stroke and heart failure, although not necessarily heart attacks. National High Blood Pressure Education Programs, beginning in 1972, urged physicians to treat blood pressure elevation, and outposts to measure blood pressure became common. The initial emphasis was on the treatment of diastolic hypertension. More recently, systolic hypertension and wide pulse pressure in seniors has been found to be serious, warranting aggressive treatment.

TREATMENT OF HYPERTENSION

President Franklin Roosevelt’s death in 1945 from severe hypertension and stroke called international attention to the consequences of hypertension and its inadequate treatment—he had been managed with diet, digitalis, and phenobarbital. Effective oral treatment became possible in 1949, first with reserpine and then with hydrochlorothiazide.104 Lumbar sympathectomy and adrenalectomy (1925), the last resort, was abandoned. Subsequently, β-adrenergic blockers, calcium channel blockers, ACE inhibitors, angiotensin receptor blocking agents, and direct renin inhibitors have brought antihypertensive relief to many (see Table 1–3). Severe salt restriction, as practiced under the external coat of the artery … as a large kind of ecchymosis … had burst through this external coat in one place, and had poured itself out within the pericardium.99 Subsequent studies have been supportive and the level where treatment should begin has been lowered, although optimal blood pressure across age groups has yet to be defined by appropriate clinical studies.

In 1913, Janeway showed that patients, once diagnosed with hypertensive heart disease and symptoms, lived an average of 4 to 5 years. However, the asymptomatic state of most patients with hypertension, the lack of effective treatment, and a prevalent view that lowering the blood pressure would be deleterious to the kidney and brain lulled most physicians into accepting the condition as being normally associated with aging. In the 1970s, reports from the Framingham Heart Study showed hypertension to be a major contributing cause to stroke, heart attack, and heart and kidney failure. Hypertension was labeled “the silent killer.” Other studies followed indicating that treatment of even mild hypertension could reduce stroke and heart failure, although not necessarily heart attacks. National High Blood Pressure Education Programs, beginning in 1972, urged physicians to treat blood pressure elevation, and outposts to measure blood pressure became common. The initial emphasis was on the treatment of diastolic hypertension. More recently, systolic hypertension and wide pulse pressure in seniors has been found to be serious, warranting aggressive treatment.

TREATMENT OF HYPERTENSION

President Franklin Roosevelt’s death in 1945 from severe hypertension and stroke called international attention to the consequences of hypertension and its inadequate treatment—he had been managed with diet, digitalis, and phenobarbital. Effective oral treatment became possible in 1949, first with reserpine and then with hydrochlorothiazide.104 Lumbar sympathectomy and adrenalectomy (1925), the last resort, was abandoned. Subsequently, β-adrenergic blockers, calcium channel blockers, ACE inhibitors, angiotensin receptor blocking agents, and direct renin inhibitors have brought antihypertensive relief to many (see Table 1–3). Severe salt restriction, as practiced earlier with the Kemper rice diet, has taken a lesser role, whereas the Dietary Approaches to Stop Hypertension (DASH) diet, exercise, and alcohol restriction are encouraged. Since 1973, recommendations published by the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure (JNC) have been very helpful. Nevertheless, the majority of patients are imperfectly controlled, and many remain undetected. Programs by the AHA focus public attention on the need for better blood pressure detection and control. As technologies continue to evolve, more direct patient engagement with ambulatory devices, including ones that can store and transmit blood pressure data via a smartphone and the Cloud, offer the possibility of much better treatment adherence and blood pressure control. From a guidelines perspective, the JNC recommendations remain the standard of care in hypertension management.105

HEART FAILURE

Medieval physicians commented on suffocative catarrh, dyspnea, asthma, orthopnea, and dropsy but failed to recognize a connection with the
heart. This was primarily because of the entrenched teachings of Galen that the purpose of the heart was to generate heat and distribute vital spirit. Marcello Malpighi believed that dyspnea could be caused by retarded circulation in the pulmonary vessels (1660s). Vieuessens (1706) and Lancisi (1707) were the first to fault the heart as the direct cause of failure, a concept more fully elaborated by Albertini (1726), 9,10

Initially, clinical observation was based on case reports describing signs and symptoms. In this setting, clinicians understood that valve obstruction, the most commonly recognized cardiac problem at that time, caused dyspnea and fluid accumulation. The autopsy findings of hypertrophy and dilatation of the heart were a particular puzzle for 18th-century physicians. Morgagni was the first to comprehend that overload from valvular disease could elicit a compensatory hypertrophic response and dilatation, leading to congestive failure (1761). At the beginning of the 19th century, Corvisart’s distinction between the causes of hypertrophy and dilatation led to an appreciation of the beneficial effects of hypertrophy and the harmful effects of dilatation. The primary role of the myocardium versus valvular disease in the production of symptoms and a basis for prognosis followed, was lost, and was then rediscovered. Richard Bright’s 1836 discovery of the relationship of cardiac hypertrophy and dropsy to shrunken kidneys introduced the kidneys as a cause of heart failure long before hypertension was known. 9 Toward the end of the 19th century, the beneficial role of hypertension was questioned by Schroetter (1876), Osler (1892), and others, who saw that it was harmful in its later stages. Mackenzie, in his influential 1908 textbook, Diseases of the Heart, stressed the functional role of the heart muscle and its reserve force, downplaying valvular disease as “an embarrasment to the heart muscle.” He believed that it was exhaustion of the heart muscle that led to symptoms and signs of heart failure. 24 His insistence that “a heart is what a heart can do” was the beginning of a functional classification that redirected thinking toward physiology and away from just the presence of murmurs and arrhythmias.

The definition of normal circulatory physiology was the precursor for an understanding of abnormal circulatory phenomena. In the late 19th and early 20th centuries, the hemodynamic physiologists Otto Frank, Ernest Starling, and Carl Wiggers established the basic principles of cardiac function, pressure, and flow abnormalities in the failing heart. 26 In the mid-20th century, studies by Sarnoff, Braunwald, and others heightened our understanding of the performance of normal and abnormal heart muscle. The widespread application of cardiac catheterization, selective angiography, and imaging studies has resulted in more precise diagnostic criteria and hemodynamic information for differentiating ischemic heart disease, hypertensive heart disease, as well as nonschemic, dilated, and hypertrophic forms of cardiomyopathies. Congestive heart failure was a term first used in the 1920s, although a definition for heart failure based on its pathogenesis has been controversial. 24 The debate initially centered on whether the elevated venous pressure was a primary or secondary event. Two opposing camps evolved: the first held that backward failure, or an upstream obstruction (eg, aortic stenosis), was the central factor, and the second championed forward failure, that is, when myocardial dysfunction with low cardiac output was the problem. Over time, the rigid concepts embodied in backward and forward failure, right-sided and left-sided failure, have given way to definitions based on the cardiac output as the discriminator: low-output and high-output failure. More recently, heart failure with reduced ejection fraction (HFrEF) and heart failure with preserved ejection fraction (HFpEF) have emerged as the preferred clinical lexicon. The discovery of B-type natriuretic peptide has revealed that the heart is also an endocrine organ. Cell biochemistry and biophysics continue to add to our understanding of the abnormalities in cardiac contraction, relaxation, and energetics, whereas molecular and cell biology are helping to define the pathways responsible for alterations in growth, offering up potential novel mechanisms for treatment.

TREATMENT OF HEART FAILURE

In the late 19th and early 20th centuries, heart failure was treated with venesection, digitalis, saline purges, a low-salt diet, mercurial cathartics, incision and drainage of edema (Southey tubes) or asctes, bromides, theophylline or urea for diuresis, and carbonic acid baths at a spa. By the 1930s, cathartics had been replaced by intramuscular mercurial injections to remove fluid. Thyroideotomy was advised in advanced cases. The introduction of potent oral diuretics, beginning with chlorothiazide (1957) and then furosemide (1964), brought miraculous relief to volume-overloaded cardiac patients, ending the common practice of twice-weekly merc shots. Cohn’s concept of afterload reduction with vasodilators (1971) soon led to nitroprusside (1974), ACE inhibitors (1981), and angiotensin receptor blockers (1992), which have greatly improved the quality of life and prognosis for heart failure patients (see Table 1–3). -Adrenergic blockers, initially thought to be absolutely contraindicated, were suggested to be otherwise in 1975 by Wagsstein and, after large-scale randomized trials demonstrated their association with marked improvements in mortality, are now a first-line treatment. Recently, use of angiotensin receptor neprilysin inhibitors has shown further reductions in mortality in HFpEF patients. How these therapies will be incorporated into the multidrug regimens of these patients still needs to be determined in practice guidelines. Unfortunately, there has been far less progress in finding effective therapies for patients with HFpEF.

The 21st century has seen an increased emphasis on aggressive device and surgical treatment for patients with advanced heart failure, especially systolic heart failure. Advanced training in heart failure and cardiac transplant is now recognized as an important subspecialty within cardiovascular medicine. 107 Biventricular pacing, introduced in 2000, has been proven beneficial in selected patients. Cardiac transplantation, once considered a last resort for selected patients after its inception in the late 1960s, has become increasingly common although limited by an insufficient organ supply. More recently, mechanical support for the failing ventricle with left (and right) ventricular assist devices (LVAD) is being used both as a bridge to cardiac transplant and as destination therapy. 108 Cell transplant therapy for cardiac repair remains a promising although still unproven approach to regenerate myocardium. 109 In addition to this increased emphasis on very aggressive treatment of the patient with advanced heart failure, important societal questions have arisen about costs of therapy, effects on quality of life, and end-of-life decision making. 110

CARDIAC SURGERY

The Nobel Prize in Physiology or Medicine in 1912 was awarded to Alexis Carrel, a French experimental surgeon working at the Rockefeller Institute, “in recognition of his work on vascular suture and the transplantation of blood vessels and organs.” His many contributions to the basic science of surgery provided the essential foundation and encouragement for the clinical surgeons who would eventually follow his bold path (see Table 1–2). A few attempts were made to suture cardiac wounds in the late 19th century and to remove pericardial adhesions and effusion or improve valvular disease in the first quarter of the 20th century; however, the surgeon was thwarted by the interrelated problems of establishing the correct diagnosis, cerebral oxygenation, pneumothorax, anesthesia, bleeding, infection, arrhythmias, blood pressure control, metabolic management, and others. 111 Comroe pointed out that 25 separate bodies of knowledge had to evolve to
permit successful open-heart surgery. Extracardiac surgery—ligation of a patent ductus by Gross (1938), repair of coarctation of the aorta by Crafoord (1944), the Blalock-Taussig shunt (1944), and removal of intracardiac missile fragments by Harken during World War II—led the way in establishing cardiac surgery as a distinct therapeutic discipline.

Simple and quick intracardiac surgery, such as repair of an atrial septal defect, was successfully accomplished using hypothermia in the 1950s by John Lewis and others, although the risk of ventricular fibrillation and air embolism presented a hazard. John Gibbons’s development of extracorporeal circulation became the essential platform for safe intracardiac surgery. In 1953, his pump-oxygenator provided 45 minutes to repair an atrial septal defect, and the surgeon finally had time to operate safely and explore new horizons. In the early 1950s, mitral stenosis was a major clinical problem, and mitral valvotomy was performed by Bailey, Harken, and Lillehei with increasing success. Surgery for congenital heart defects was next, including tetralogy of Fallot (Lillehei, 1954). More complicated surgery, including mechani-
cal prosthetic valve replacement (Starr and Harken, 1960), homograft valve (Donald Ross, 1962), cardiac transplantation (Christiaan Barnard and Norman Shumway, 1967), bioprosthetic valve replacement (1970), mitral valve repair (Alain Carpentier, 1971), and repair of complex congenital heart disease followed as diagnostic and surgical techniques, artificial valves, and intensive postoperative care improved.

In 1910, Alexis Carrel attempted the first experimental coronary bypass, fashioning an anastomosis between the descending aorta and the left coronary artery. Efforts to improve the coronary circulation using pericardial irritants (Beck, 1934), omental or pectoral grafts (O’Shaunessy, Beck, 1930s), internal mammary implants tunneled directly into the heart muscle (Vineberg, 1950), and coronary endarterectomy (Bailey, Long-mire, 1956) were touted but provided inconsistent clinical benefit. Vaselli Kolesov, in Russia, pioneered internal mammary to coronary artery bypass grafts beginning in 1964 and, in 1962, David Sabiston performed a coronary bypass using a patient’s leg vein but the patient died following the operation. René Favaloro, an Argentine cardiac surgeon working at the Cleveland Clinic, is usually credited for successfully ushering in the era of coronary bypass surgery (1968). Coronary artery bypass graft surgery remains one of the mainstays in the treatment of advanced coronary artery disease and one of the most frequently performed surgical operations. Widespread use of arterial conduits as bypass grafts has improved both the long-term patency of grafts as well as the survival benefit of the operation.

Aortic surgery, initially dealing with late-stage complications, advanced from the ligation of aortic aneurysms to wrapping the aorta with various materials and finally to resection. Attempted surgical repair of aortic dissection dates from 1935, but operative success was not achieved until 1954 when DeBakey, Cooley, and Creech reestablished aortic continuity. Vascular reconstruction and endarterectomy, insertion of prosthetic grafts, percutaneous insertion of endovascular grafts for aneurysms and dissection (1991), and stenting of carotid artery stenosis (1997) have transformed the management of vascular disease.

Mortality rates from all cardiac surgery have progressively fallen while surgeons have offered increasingly complex surgeries to an older population with increasing numbers of cardiac and noncardiac comorbidities. Cardiac transplantation has become common and the use of LVADs as destination therapy is increasing, but attempts to manufacture an artificial heart have been disappointing. Off-pump and robotic-assisted surgery are routine in many centers although some uncertainties remain in establishing their incremental benefit over other standard techniques. Increasingly, surgeons and interventional specialists are collaborating in offering hybrid procedures and advanced endovascular care that require the skills and expertise of both groups of providers.

### CARDIOVASCULAR CARE IN THE 21ST CENTURY

Although clinical outcomes among patients with a variety of cardiac diseases have improved over recent decades, the incidence of diseases such as heart failure and ischemic heart disease continues to increase as the population ages. Additionally, as the globe grows increasingly smaller and previously rural populations are exposed to modern Western diets and habits such as tobacco use, there has been an explosion of atherosclerotic disease around the world, including in countries with emerging economies. The global epidemics of obesity, diabetes, and cardiovascular disease require global collaborations addressing prevention, detection, and treatment of cardiac disease (http://www.heart-federation.org).

The practice of cardiovascular medicine has evolved as well from one centered on observation and treatment based on empiricism to one reliant on science, guidelines, and the delivery of measurable quality care. The challenge of the next decade will be to establish which therapies truly work best for which patients, to move toward the goal of precision health/medicine, and to advocate for the successful delivery of those therapies to patients with cardiovascular disease.

Imaging technologies will continue to improve in their technical sophistication, but societal cost demands will place the burden for establishing their incremental benefit back on the cardiovascular community, which must be poised to both understand and participate in the required research that demonstrates the added/incremental value. Endovascular and surgical techniques will evolve and encourage greater collaboration among sub-sub-specialists to offer state-of-the-art vascular care to an increasingly older population afflicted with multiple cardiac and noncardiac comorbid conditions. Concepts related to multidisciplinary care teams will become increasingly important as care becomes increasingly complex, requiring the expertise and talents of diverse groups of professionals. Notions of patient-centric care and engagement of patients in collaborative decision making with clinical providers around their care will be central to cardiovascular practice and research. Measuring and reporting patient outcomes will be critical in advancing cardiovascular care, and demonstrating quality and value will be critical in a health care system increasingly pressured to reduce costs while raising quality.

### REFERENCES


---

#### Sources

- **The History of Cardiology**
- **A History of the Heart and the Circulation**
- **Cardiovascular Diseases Since Harvey’s Discovery**
- **A View from the Millennium: The Practice of Cardiology Circa 1950 and Thereafter**
- **Global Burden of Cardiovascular Diseases: Part I**
- **Global Burden of Disease Study 2010**
- **Years of Life Lost (YLLs) and Years Lived with Disability (YLDs)**
- **Disability-Adjusted Life Years (DALYs)**

---

**119** References to the Global Burden of Disease Study 2010 are included in the text for detailed data and analyses.


35. Cleland JG, Calvert MJ, Verboven Y, Freemantle N. Effects of cardiac resynchronization therapy on long-term quality of life: an analysis from the CArdiac REsynchroni-

36. Cleland JG, Calvert MJ, Verboven Y, Freemantle N. Effects of cardiac resynchronization therapy on long-term quality of life: an analysis from the CArdiac REsynchroni-


SECTION 1: Cardiovascular Disease: Past, Present, and Future


110. Thompson JS, Matlock DD, Mcclellan CK, Jenkins AR, Allen LA. Development of a decision aid for patients with advanced heart failure considering a destination therapy left ventricular assist device. JACC Heart Fail. 2015;3(12):965-976.


