Modern cardiology owes much of its success and identity to a long series of spectacular technological advances and procedural innovations. Beginning more than a century ago, technology not only revolutionized the way doctors evaluated their patients, but it also transformed the way patients viewed their doctors. Specialists began to be identified, in part, by the equipment they used and the tests and procedures they performed. Our contemporary enthusiasm for medical technology, despite its cost and complexity, reflects the conviction that it contributes significantly to the diagnosis and treatment of cardiovascular disease.

Earlier generations of doctors and patients embraced the technologies of their time, and they shared our fascination with new diagnostic tools and techniques. The discovery of X-rays in 1895 and the invention of the electrocardiograph (ECG) seven years later heralded a new era in medical practice that saw instruments of precision, machines, and procedures replace the physician’s unaided senses and the stethoscope as the primary tools of cardiac diagnosis. This trend continues today because physicians and patients alike value objective and accurate analysis of the heart’s structure and function. Modern medical technology is fantastically fertile. Sophisticated machines generate incredible images and mountains of data. Contemporary technology is so powerful and seductive that it has claimed center stage in cardiovascular care. A decade ago British cardiologist John Goodwin wrote, “The appeal of technological investigation is irresistible. The young cardiologist, vibrating with passionate desire to analyze the instrumental results, cannot always see the point of laborious clinical examination” (1). Finances, of course, help fuel our infatuation with technology.

TECHNOLOGY TRANSFORMS DIAGNOSIS

Powerful economic forces catalyze the multifactorial equation that defines the search for—and eventual application of—new tools and techniques to help diagnose illness and treat patients. The ultimate goal of all this creative energy is to help men, women, and children with cardiovascular disease. During the past century, the pace of discovery, invention, and innovation in medicine has accelerated dramatically. A combination of altruism and entrepreneurialism ignited the creativity that culminated in countless practical advances. This phenomenon is apparent if one looks back even further—to 1816—when the French physician and pathologist René Laennec invented the stethoscope. Three years later he publicized the unique value of his invention in a two-volume monograph. Laennec also manufactured and sold the earliest stethoscopes, which were simple cylindrical tubes made of wood. One end of the instrument was placed on the patient’s chest, while the other end was applied to the examiner’s ear.

In retrospect, the stethoscope was more than a simple tool to help doctors listen to sounds coming from the heart and lungs. Although Laennec and other early advocates of auscultation could not appreciate it, the simple instrument transformed the way doctors searched for disease. In a figurative sense the stethoscope transported physicians seeking a cardiac or pulmonary diagnosis inside their patients. It also signaled the transformation of medical diagnosis from a passive process—whereby physicians listened to their patients’ complaints, palpated the pulse, and looked at their body and urine—into an active process, whereby doctors used all sorts of instruments and machines to aid their senses. During the middle third of the nineteenth century, a multitude of “scopes” were invented to probe other organs and orifices, both figuratively and literally.

In 1895, the concept of “looking” inside a patient changed forever. When German physicist Wilhelm Röntgen discovered X-rays that year, he gave physicians a powerful technique that made the skin transparent and the bones and internal organs visible. In terms of cardiology, this dramatic scientific discovery also meant that doctors could measure the heart’s size and watch it move (once the fluoroscope was invented in 1896). As useful as the X-ray was for studying the heart and lungs, it was not focused on any specific organ. The ECG, by contrast, was an invention that not only targeted a single organ; it catalyzed the creation of a clinical specialty: cardiology.

The 1902 invention of the ECG by Dutch physiologist Willem Einthoven gave physicians a powerful tool to help them diagnose various forms of heart disease (2). Like Laennec’s stethoscope and Röntgen’s X-rays, Einthoven’s ECG spoke for itself. Each of these innovations provided unique information that promised to unlock a few more of the heart’s secrets. The ECG’s unique value in identifying and characterizing cardiac arrhythmias was apparent immediately. Physicians and researchers interested in heart dis-
ease and cardiac physiology used the instrument to study disorders of the heartbeat.

Gradually, it became apparent that the ECG’s value was not limited to cardiac arrhythmias. In 1919, James Herrick, a Chicago physician who had described the clinical syndrome of acute myocardial infarction (AMI) nine years earlier, reported distinctive T-wave changes on the ECG that accompanied coronary thrombosis. This discovery stimulated even more interest in the ECG as a clinical tool and greatly enhanced the physician’s ability to recognize AMI.

Reflecting on “the development of the science of diagnosis,” Johns Hopkins internist Lewellys Barker declared in 1917, “A physician that went to sleep in 1890 and woke up yesterday would find himself a disoriented Rip Van Winkle in diagnosis, with utterly antiquated ideas and information. The diagnostician that sleeps longer than eight or nine hours at a stretch in these days runs a risk!”(3). Barker’s Rip Van Winkle would have slept through the discovery of X-rays, the invention of the ECG, the introduction of the sphygmomanometer, and the development of a multitude of serological and laboratory tests.

THE INVENTION OF CARDIOLOGY

America’s first practitioner cardiologist, Louis F. Bishop of New York City, was wide awake during this dynamic era of medical discovery and invention. During the second decade of the 20th century, he incorporated several recent technological advances into his growing cardiology practice. Meanwhile, his decision to equip his private office with an ECG machine, X-ray apparatus, and pulse-recording equipment reinforced his identity as a heart specialist. So, technology not only helped Bishop define the scope of his practice, but it also made it easier for his peers and patients to see that he was a specific type of doctor—a cardiologist. Cardiology was then a totally new specialty that Bishop and a few other American and European physicians were defining. A specialty framed, to a significant degree, in terms of technology. In 1922, Bishop advocated the routine use of the ECG machine, X-ray, and fluoroscope as part of a “complete cardiological examination of every patient” with known or suspected heart disease (4).

The first-generation cardiologists in the U.S. and Europe (who invented the specialty between the World Wars) relied on the stethoscope, sphygmomanometer, ECG machine, chest X-ray, and fluoroscope to help them evaluate and manage heart patients. Several of the tools and technologies they used were enhanced from a functional standpoint during the 1930s. For example, that was when the clinical value of precordial ECG leads was described and truly portable ECG machines were invented. There were no major technological “breakthroughs” to rival the discovery of X-rays or the invention of the ECG, however. The next major wave of technological and procedural innovation that transformed cardiology practice owed much to discoveries and inventions that were unanticipated byproducts of military research.

The pace of medical invention and innovation in the U.S. accelerated dramatically after World War II, when the federal government began to spend millions (and eventually billions) of dollars on research. Meanwhile, the field of biomedical engineering emerged, and many private companies were formed around the world to adapt technological advances such as the transistor and the computer for use in diagnosis and treatment. Cardiology, as much as any specialty, has benefitted from the tremendous technological advances of the past half-century. There isn’t enough space here even to list all the new procedures and equipment that resulted from a frenzy of public and private research and development.

THE CARDIAC CATHETER AS A CLINICIAN’S TOOL

Just as the ECG helped define and develop cardiology during the first half of the 20th century, the cardiac catheter catalyzed the specialty during the second half of the century. In 1929, German surgical resident Werner Forssmann published the results of his self-experiment that demonstrated right heart catheterization was possible and safe in humans. Soon, several radiologists, physiologists, and physicians in Europe and the Americas adapted the cardiac catheter to help them answer various clinical and research questions. For example, angiography, invented in the 1930s, used the catheter as a conduit for the injection of contrast material to visualize the cardiac chambers and identify intracardiac shunts.

In 1941, André Cournand and his colleagues in New York City published the first of a series of papers that demonstrated the value of the cardiac catheter as a tool for studying cardiopulmonary physiology in humans. Shortly thereafter, two things helped transform cardiac catheterization from a physiologist’s research tool into a clinical cardiologist’s diagnostic technique: 1) concern about the physiology and treatment of shock during World War II and 2) the invention of the Blalock-Taussig “blue baby” operation in 1944. Dramatic advances in cardiac surgery during the 1950s, especially the invention of open-heart surgery using the heart–lung machine, stimulated the creation of hundreds of cardiac catheterization laboratories in academic medical centers and referral hospitals in the U.S.

The invention of selective coronary angiography by Mason Sones in 1958 had an extraordinary effect on cardiology and cardiac surgery. This technique was based on a combination of procedural innovations and technological developments dating back to the discovery of X-rays in 1895. When Sone’s surgical colleague René Favaloro reported his early experience with saphenous vein coronary artery bypass surgery for angina pectoris in 1968 and 1969, he emphasized that coronary angiography was an indispensable part of patient selection. It also provided surgeons with a road map to help them plan their operation. During the 1970s,
demand for cardiologists trained to perform coronary angiography grew dramatically, and the procedure diffused rapidly.

The many technological and procedural advances that were critical for the introduction of open-heart surgery and invasive cardiology (and many other mid-century heart care innovations) resulted from the productive collaboration of clinicians, scientists, engineers, physiologists, and individuals representing many other disciplines. At the same time, huge increases in public research and health care funding and private capital investment accelerated the pace of invention and innovation. The collaborative model of research and development was so effective that the number of industry–academic projects and partnerships increased dramatically during the final third of the 20th century.

NONINVASIVE DIAGNOSIS

Meanwhile, noninvasive diagnostic techniques were introduced that provided clinically useful information in many cardiac disorders. Like so many medical–technological advances during the second half of the 20th century, echocardiography was a byproduct of military research. It evolved from sonar and radar technology. Although Inge Edler and Helmhut Hertz of Sweden published a pioneering paper on cardiac ultrasound in 1954, the technique was not widely used until the early 1970s. By this time, several groups had reported its unique role in the diagnosis of pericardial effusion and the evaluation of valve abnormalities and left ventricular function. During the past quarter-century, clinical echocardiography grew dramatically with the introduction of two-dimensional echo, Doppler and color-flow Doppler echo, transesophageal echo, and stress echo.

Modern nuclear cardiology techniques can be traced to Swedish physiologist Goran Liljestrand in 1939. After 1970, when the clinical potential of nuclear cardiology had become evident, many technical and procedural innovations led to an ever-expanding list of applications. Because the equipment required for nuclear cardiology procedures is larger and more expensive than echocardiography machines, this technology has been based mainly in hospitals. Moreover, government requirements for the handling and use of radioisotopes moderated the number of cardiologists involved in nuclear cardiology procedures as compared with echocardiography.

CORONARY CARE UNIT AND ARRHYTHMIA MANAGEMENT

Technology drove another series of innovations that revolutionized the care of cardiac patients in recent decades. Reported between 1961 and 1963, the cardiac arrest team and coronary care unit (CCU) concepts integrated several technological advances that made it possible to promptly identify and treat life-threatening cardiac arrhythmias. I will mention just three technological factors in the cardiac care equation. The invention of the cathode ray oscilloscope permitted constant ECG monitoring. Temporary pacemakers, developed in the 1950s, gave doctors a tool to treat symptomatic bradyarrhythmias and heart block. The invention of the defibrillator made it possible to terminate ventricular fibrillation, an arrhythmia that was invariably fatal before this innovation.

Teamwork, a feature of the operating room since the late nineteenth century, was embraced by cardiologists as technology and therapeutics were blended into new paradigms of heart care. Special training was necessary to apply the new diagnostic and therapeutic technologies and techniques successfully. In the CCU, for example, specially trained nurses were given unprecedented authority to diagnose and treat life-threatening arrhythmias. The dramatic life-saving potential of the CCU led to its rapid diffusion to most community hospitals in the U.S. during the late 1960s and 1970s. As a result of this and related technological developments such as selective coronary angiography, the job market for cardiologists grew phenomenally during the decade.

Clinical cardiac electrophysiology (EP) is another example of the value of interdisciplinary collaboration and the power of the marketplace to generate capital for investment in biomedical research and development. The origins of clinical EP and pacing can be traced to basic EP research in the middle of the 19th century (5). The advent of the ECG 100 years ago and the development of cardiac catheterization techniques a half-century ago gave specialists the tools they needed to investigate the subtleties of cardiac arrhythmias in humans. Decades of research and technological innovation paid off with the introduction of the transistorized implantable cardiac pacemaker in 1960 and the development of the automatic implantable defibrillator two decades later.

THE FUTURE

Technology will continue to help define and direct cardiac care for the foreseeable future. Some technological innovations will be used to help doctors diagnose and treat cardiovascular disorders, while others will facilitate basic research aimed at preventing disease in the first place. As new technologies and the various tests and procedures they support are introduced into practice, physicians have a social responsibility to use these innovations wisely. Together with our patients and their families, doctors must become more comfortable acknowledging that health care resources are finite. Many things contribute to the complex equation of health care costs in the U.S. and other countries, but technology is an important factor. If cardiovascular specialists hope to have access to new, cost-effective technologies, then we must be willing to make informed choices.

The American College of Cardiology, in partnership with the American Heart Association and the subspecialty societies, develops guidelines to help doctors choose wisely when it comes to technologies and procedures. Technology,
which should supplement clinical judgment rather than replace it, can be life enhancing and even life saving. It often helps physicians make the correct diagnosis and initiate optimal therapy. Although many of our current clinical technologies are complementary, some provide redundant information that adds nothing but cost when used to evaluate the same problem in a single patient. The question cardiologists should ask each time we consider ordering or performing a test or a procedure is whether the results will truly influence the patient’s care or outcome. If the answer is no, then there is rarely any reason to perform it or justification to bill for it. In the long run, everyone wins if we use technology responsibly. The future of cardiology is bright, and unimaginable technological innovations will help shape and enhance that future—just as technology has helped define the specialty as we know it today.

REFERENCES