Early angiography (here a scene from the 1950s) combined technical skills with dexterity and split-second timing. (Courtesy of the Center for the American History of Radiology, Reston, Va.)
The last century has witnessed extraordinary advances in our capacity to define both the borders of the heart and the interior anatomy of its chambers in living subjects. Fluoroscopy and radiography were employed and described in 1896 within months after Röntgen presented his seminal papers. In the early part of the twentieth century, the plain film findings in heart disease began systematically to be characterized and then recorded in the literature.

Although angiocardiology was based on developments in the 1920s and before, its introduction in clinical subjects awaited the 1930s, and its evolution to its modern form took place in the 1940s and 1950s, side by side with aortography. At a somewhat later stage, the feasibility of coronary arteriography was demonstrated and its use spread widely during the 1960s.

Echocardiography, isotope studies of the heart, computed tomography (CT), and magnetic resonance (MR) imaging were all products of a later period. This account focuses primarily on conventional radiology and angiocardiology; echocardiography and cardiovascular nuclear medicine are dealt with elsewhere in this volume.

**Conventional Radiography and Fluoroscopy**

By early January 1896 word of Röntgen's discovery and its import had spread around the world. Almost immediately, the possibilities of applying the "new photography" to traumatic lesions of bone fired the imagination and, within a month, X rays of fractures and of many other abnormalities had been obtained and published. Early in the year Thomas Edison and many others began intensive work on the fluoroscope. By the end of March 1896 Becher had outlined the stomach and intestines of a sacrificed guinea pig with lead subacetate and mentioned the idea of delineating fistulas in this way.

In the fall of 1896 Walter B. Cannon, one of our great physiologists, studied and described the nature and site of peristaltic activity in cats as he saw it on the fluoroscopic screen.

In April 1896, five months after the discovery of X rays, Francis H. Williams of Boston used fluoroscopy to examine a man with gross cardiomegaly. He also described the fluoroscopic findings in pericardial effusion and, within the next few years, examined hundreds of patients, describing many of his find-
ings and comparing the heart size with that determined by percussion.5,6,7

William Morton was a pioneer American radiologist whose published work in 1896 showed a radiograph demonstrating the human heart.8 By 1898, when David Walsh wrote The Roentgen Rays in Medical Work, he was able to reproduce a chest film that clearly showed the position and dimensions of the heart and to describe a number of cardiac and aortic conditions as visualized radiographically.9 The X-ray in his book required an exposure time of twenty minutes, with the tube only 30 inches from the X-ray plate (Fig. 10.1). In 1902 Albert Abrams of San Francisco assessed normal cardiac size, and in the years that followed there were many efforts to estimate the limits of normal, using fluoroscopy, orthodiagnosis (tracing the cardiac shadow on transparent paper attached to the fluoroscopic screen), and radiography.10 When Williams wrote his book, The Roentgen Rays in Medicine and Surgery in 1903, he devoted sixty-two pages to the heart.11 That same year, intracardiac calcification was first identified in fluoroscopy by a radiologist named Rudis-Jicinsky from Cedar Rapids.12 Kassanian’s textbook in 1907 published a table of normal cardiac size developed by Moritz in Germany and, a few years later, Claytor and Merrill attempted to quantitate heart size in its relationship to body size and illustrated many lesions with orthodiagrams (Fig. 10.2).13,14

As the second decade of the twentieth century unfolded, technological improvements in tubes and equipment afforded enhanced resolution. Bardeen in 1915 related cardiac area and volume to height, weight, and sex.15 In 1919 Danzer described the cardiothoracic ratio, with the normal heart usually less than half the largest diameter of the thorax.16 The problems of cardiac measurement occupied many radiologists and cardiologists over the years, until the early 1940s, when Ungerleider and Gubner produced a nomogram relating frontal cardiac area to values predicted from body height and weight.17 Even this has long since faded from broad application, while the cardiothoracic ratio and the volumetric measurements are still generally used, with the understanding that there is a large range of normal variation.

By the 1920s there was a voluminous literature on the radiology of the heart, and in October 1920 Eyster and Meek reported they were obtaining radiographs of the human heart at different points in the cardiac cycle, using simultaneous electrocardiographic trac-
ings to record the moment of exposure. In 1922 Karshner and Kennicott described radiographic findings in mitral stenosis with pulmonary edema, mitral regurgitation, aortic regurgitation, and pericardial effusion. Meanwhile, Vaquez and Bordet published a book devoted to the radiology of the heart and the aorta.

In 1929 Paul Dudley White, the eminent American cardiologist, presented a lecture before the American Roentgen Ray Society (ARRS), in which he evaluated radiology's strengths and weaknesses. He concluded:

In the first place, the roentgen ray affords by far the most accurate measurements of heart size and heart shape that we possess in the clinic.

Second, in the presence of obesity, emphysema, and other complications which render physical examination of the heart very imperfect, the roentgen ray affords sometimes the only means of determining heart size and shape.

Third, surprising and unexpected findings like pericardial calcification or aneurysms of the aorta are sometimes revealed by roentgen study alone, and in themselves justify a routine employment of this method of examination wherever possible.

Fourth, the size of the aorta and of the left auricle, and even sometimes of the left ventricle, can be determined only by the roentgen ray.

Fifth, abnormalities of the hilus shadows and of the pulmonary artery are important findings to be discovered only by the roentgen ray, and

Sixth, roentgen-ray observation of peculiarities of the actual pulsation of the heart and great vessels is alone worth the trouble of applying this method of study.

Unlike many cardiologists of the era, White had given credit where credit was due and had rendered a succinct summary of the usefulness of the X rays in studying the human heart in vivo. Coming from so widely recognized an international authority, his comments had a powerful effect on stimulating greater use of radiology in the diagnosis of heart disease.

Polevski, in his 1934 book, The Heart Visible, focused exclusively on the radiology of the heart and devoted two hundred pages to a description of the normal and the abnormal, with excellent illustrations (Fig. 10.3). In it he emphasized that the radiologist must familiarize himself with the anatomy and the normal and disturbed physiology of the heart and component chambers, as well as of the large vessels.

THE HEART VISIBLE
A CLINICAL STUDY IN CARDIOVASCULAR ROENTGENOLOGY IN HEALTH AND DISEASE

By J. Polevski, M.D.
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It is clear today, sixty years later, that Polevski's admonition was well grounded; the plain film of the chest is a repository of information about pulmonary arterial and venous pressures, cardiac size, individual chamber enlargement, and major vessel disease that can only be thoroughly analyzed by those with a firm grounding in anatomy and cardiac pathophysiology.

It remained for Hugo Roesler in 1937 to bring both his large personal experience and the world literature together in a three hundred page textbook, The Radiology of the Heart. The illustrations in this textbook are comparable to many in the contemporary literature.

In 1932 Case reported the observation of pericardial calcification. The next year, Elliott Cutler and Merrill Sosman at the Peter Bent Brigham Hospital described valve calcification in a patient who had had rheumatic heart disease. Ten years later Sosman and Wosika reported twenty-three cases of calcification. Over the ensuing years, the usefulness of fluoroscopy in detecting intracardiac calcification was repeatedly emphasized.
Congenital heart disease also received a good deal of attention. The first description of patent ductus arteriosus goes back to 1898; by 1919 Hubeny reviewed forty-one cases at the ARRS meeting. Coarctation of the aorta was also described in detail, and Polevski discussed and illustrated the coarctation of the aorta at the baby of Fallot, transposition of the great vessels, and other anomalies (Fig. 10.4). Maude Abbott in her classic Atlas of Congenital Heart Disease of 1936 and Helen Taussig in her book of 1947 did much to clarify the anatomy of congenital heart disease and the plain film findings in many simple and complex anomalies.

Throughout the period when conventional fluoroscopy and radiography were being applied increasingly to patients with heart disease, kymography (recording segmented border motion with a moving roentgenographic slit aperture) was developed and widely utilized as a means of studying border motion. It remains of more or less historic interest. It gave way to electrokymography (recording border motion radiographically and transforming the record electronically into a wave form) in the 1940s, which was the subject of many investigations until it gradually faded into the dustbin of medical history.

**Angiocardiography**

Visualization of human blood vessels was achieved early. In January 1896, during the month after the announcement of Röntgen’s discovery, Haschek and Lindenthal injected Teichmann’s mixture into the blood vessels of an amputated hand. A published photograph of their original roentgenogram showed clearly the potential of the method for visualizing the vascular bed (Fig. 10.5). Morton’s book of 1895 is of interest in this regard. He commented:

In teaching the anatomy of the blood vessels, the X ray opens out a new and feasible method. The arteries and veins of dead bodies may be injected with a substance opaque to the X ray and thus, their distribution may be more accurately followed than by any possible dissection. The feasibility of this method applies equally well to the study of the structures and organs of the dead body. To a certain extent, therefore, X-ray photography may replace both dissection and vivisection, and in the living body, the location and size of a hollow organ may be ascertained.

At the time that Voelcker and von Lichtenberg introduced retrograde pyelography to the field of urologic diagnosis in 1906, a number of medical schools had already organized departments of roentgenology.

In 1920 an X-ray atlas devoted only to the systemic arteries of the body was published in England. In it were roentgenographic reproductions which showed with great clarity the blood vessels in cadavers. Just three years later, in 1923, X rays of arteries would demonstrate the blood vessels of live patients rather than corpses.

Otto Franck and Walter Alvens, in 1910, introduced a suspension of bis-

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Fig. 10.4 Chest roentgenogram of a child with complete transposition of the great vessels, from Polevski, 1934. Note the cardiac enlargement and pulmonary plethora characteristic of this anomaly. (Author’s collection)

Fig. 10.5 Roentgen picture of an amputated hand filled with Teichmann’s mixture. Made by E. Haschek and C. Lindenthal in Vienna in January 1896. (Author’s collection)
muth and oil into the hearts of dogs and rabbits directly through the large veins.\(^{38}\) They were able to observe the passage of the oily droplets from the heart into the lungs. The work of Jean Sicard and Jacques Forestier twelve years later represented the next major advance.\(^{39}\) They had employed Lipiodol, an early oil-based contrast medium, to study first the bronchial tree and then the spinal subarachnoid space in 1922. A year later, they decided to try the oil in the cardiovascular system. Working with dogs, they slowly injected 5 cubic centimeters (cc.) of Lipiodol into the femoral vein and, with the aid of fluoroscopy, watched the droplets move with increasing speed from the iliac vein into the heart. The Lipiodol was then “pulverized” by ventricular contraction, thrown with great speed into the pulmonary artery, and finally spread as multiple emboli into the small vessels of the lung, disappearing in ten to twelve minutes. Emboldened by their success in dogs, they repeated the experiment with human subjects, in whom they carefully observed the course of the opaque oil from the antecubital vein to the pulmonary capillaries. Their patients coughed as the oil reached the lungs but suffered no other ill effects.

In the same year, 1925, Joseph Berberich and Samson Hirsch reported the first arteriograms and venograms obtained in man, with 20 percent strontium bromide.\(^{40}\) One year later, in 1926, Barney Brooks described the intra-arterial injection of sodium iodide as a means of demonstrating the vessels of the lower extremity in man.\(^{41}\)

The 1920s, then, were an exciting developmental period for the field of vascular radiology, with pioneering work that would ultimately lead to angiocardiology. In 1928 Egas Moniz described carotid angiography and its application to the study of cerebral lesions.\(^{42}\) During the same year Werner Forssmann, having practiced on a cadaver, inserted a catheter into his own antecubital vein until he felt that it had reached the right atrium (Fig. 10.6).\(^{43}\) With the catheter hanging out of his arm, he walked down a few steps and then proceeded along a corridor in the hospital basement in order to reach the radiographic room. The roentgenogram he obtained confirmed his belief that the catheter tip was, in fact, in the right atrium.

Within two weeks Forssmann wrote a paper on cardiac catheterization which was accepted for publication. Soon after, he moved to the University Hospital for Surgery in Berlin with the hope of pursuing a career with adequate time for research. Five weeks later, when his article was published, the hospital chief received a letter accusing Forssmann of having “stolen” the method, in spite of the fact that no one before him had suggested catheterizing the human heart (Fig. 10.7). Ultimately Forssmann was dismissed from the University Hospital and was able to continue his experiments in a small county hospital for a time. Originally he had conceived of the catheter as a means of infusing therapeutic substances into the heart, but in 1931 he undertook to visualize the right heart and the pulmonary vessels with Uroselectan. He succeeded in dogs but not in human subjects.

In spite of the disapproval of his University Hospital chief in 1928, many years later, in 1956, Forssmann was awarded the Nobel Prize in medicine, together with André Cournand and
Dickinson Richards. His extraordinary contribution led not only to selective angiocardiography but also to major advances in our knowledge of pulmonary and cardiac physiology.

In 1929 Reynaldo dos Santos showed that satisfactory opacification of the abdominal aorta and its branches could be obtained by using transumbilical needle puncture and injection. Portuguese investigators, pioneers in the field of angiography, also addressed themselves to the problem of showing the pulmonary vessels in disease. Moniz and his colleagues devised the technique of angiosprouxyography (injecting a contrast material either through a catheter in the right atrium or intravenously to opacify the pulmonary vessels) and described the appearance of the pulmonary vessels in a variety of conditions in 1931. They were unable to visualize the cardiac chambers.

The development of less toxic contrast agents remained a challenge until 1929, when Swick reported the use of an organic iodide, known as Selectan. Soon thereafter, Abrochil (Skiodan) was synthesized, and by 1931 it had been employed in arteriography and venography with gratifying results.

In 1933 Peter Routhorst working with rabbits, described the opacifica-

Fig. 10.7 Forssmann's article describing cardiac catheterization, which was subsequently used to attempt opacification of the cardiac chambers in humans. (Author's collection)

Fig. 10.8 Agustin Castellanos (b. 1902), the first to perform angiocardiography in patients with congenital heart disease. (Author's collection)
radiologic images are very clear, when the details we mention under "technique" are heeded. Their report constituted an astonishingly complete summary of a carefully conceived and well-executed investigation of the possibilities of angiocardiography, the name they applied to this technique. Between September 1937 and July 1938 they published many papers in a number of journals, elaborating on the technique and summarizing the diagnostic criteria.

By July 1938, when George Robb and Israel Steinberg independently reported the successful opacification of the right and left cardiac chambers, Castellanos and his group had described the angiocardiographic appearance of many of the entities virtually as we know them today. They had published illustrations of atrial and ventricular septal defects, pulmonic stenosis, the tetralogy of Fallot, transposition of the great vessels, and other anomalies (Fig. 10.9); had suggested and performed biplane studies; and had devised an automatic injection device which they described in some detail. Their initial contributions were wide ranging.

One gap in their method of investigating the heart in the living subject was that without serial films they were able to opacify adequately only the right heart chambers. Actually, this was sufficient for establishing the diagnosis in many congenital anomalies, since it demonstrated the transposed or "overriding" aorta, pulmonic stenosis, and, at times, defects in the cardiac septa. Another early limitation they encountered was that satisfactory visualization occurred inconsistently. By May of 1938, however, they reported success in children up to the age of fourteen.

Robb and Steinberg in 1938 introduced the use of ether and cyanide circulation times as a guide to the timing of the successive exposures in order to obtain sequential opacification of the right and left heart. Their technique was applicable to adults, and they further suggested the possibility of utilizing cineradiography and rapid serial roentgenography and of coordinating the exposure with the heartbeat. By January 1939 they were able to report on 238 injections made in 127 patients, of whom 42 were normal, 47 had pulmonic disease, and 38 had heart disease (Fig. 10.10). They found that angiography could differentiate between prominent pulmonary vessels and mediastinal or hilar masses and that the technique could demonstrate characteristic changes in congenital, rheumatic, pulmonary, hypertensive, and aortic heart disease as well. As a
result of their independent contributions, angiocardiology became a more versatile and reliable diagnostic tool, permitting opacification of all four cardiac chambers and the great vessels.

Sussman and his group at Mount Sinai Hospital in New York, meanwhile, were exploring the possibilities of angiocardiology in congenital and acquired heart disease. They published the first of a series of excellent papers in 1941 and designed a practical device for multiple exposures during angiocardiology.55

From 1943 until about 1947 there was a hiatus in the literature, and few significant contributions appeared. During much of this period the second World War was underway, and the energy of physician-investigators in the United States, Europe, and East Asia was focused sharply on the needs of those in uniform. Castellanos and his group continued to elaborate on some of their previously published material, and in 1948 published a volume on congenital heart disease in which they summarized their clinical knowledge, their angiocardio graphic findings, and their experience with retrograde aortography.56 In 1947 Ignazio Chavez and his co-workers described in detail a technique for intracardiac angiocardiography, injecting the opaque medium directly into the heart through a catheter.57 Gunnar Jönsson and his associates at the South Hospital in Stockholm used this method of "selective" angiocardiology extensively and obtained excellent opacification of the cardiac chambers.58

Charles Dotter and Steinberg, meanwhile, were intensively investigating the applications of angiocardiology to pulmonary and cardiac disease in adults, and in 1951 published an excellent volume on angiocardiology summarizing their experience.59 In Sweden, Sven Kjellberg, Ulf Ruche, and their collaborators were performing superb correlative studies of the clinical, laboratory, radiologic, angiographic, and pathologic aspects of congenital heart disease. This material was brought together in a comprehensive monograph published in 1955.60

Technical advances included the development of a rapid film changer by Gidlund and of biplane film changers by Axen and John Lind, and the movement toward practical image amplification suggested by Edward Chamberlain in 1942 and subsequently developed by Colman in 1948 and by Sturm and Russell Morgan in 1949.61,62,63,64,65

Meanwhile, the attractiveness of applying cineradiography to the study of heart disease had long been evident, but the limitations, namely poor detail and relatively high radiation exposure, were serious. They did not, however, prevent a thorough and careful investigation of cineradiologic technics. As early as 1896 Macintyre undertook studies in roentgen cinematography.66 Thereafter, there were sporadic attempts to use the method until the 1930s, when Reynolds, Janker, Stewart, Barclay, and others restudied its application to a number of problems.67,68,69,70,71,72,73,74 The decade that followed witnessed continued activity on the part of Janker and his co-workers, organization of an active cine program at the University of Rochester, and a number of significant technical developments, including higher resolution screens and better generators.75

The major and obvious advantage of fluoroscopy over roentgenography lay in the opportunity it afforded to study motion. The pulsation of the heart and aorta could be analyzed visually and the pulmonary vessels studied during different phases of the cardiac cycle. A disadvantage was its failure to yield a permanent record. Motion picture photography of the fluoroscopic screen provided a permanent recording of cardiac movement—both external and internal—available for study and restudy.

It was inevitable that efforts to obtain recordings of cardiac dimensions would be undertaken. Carleton Chapman and his co-workers described the use of biplane cinefluorography to evaluate ventricular volume in 1958, and in the same year H. L. Abrams introduced biplane image amplified cineangiography which has since
become the most widely applied contrast method of studying children with congenital heart disease.\textsuperscript{76,77}

**THORACIC AORTOGRAPHY**

The development of thoracic aortography paralleled that of angiography. Although contrast visualization of the abdominal aorta was accomplished in 1929, it was not until 1936 that Innocenzo Nuvoli described thoracic aortography in humans.\textsuperscript{78} His method of aortic puncture utilized a bone marrow needle to perforate the skin, the subcutaneous tissue, and the sternum in the midline at the level of the second intercostal space. Using 100 percent sodium iodide, he injected 28 cc. of this solution under constant pressure and exposed two films, the first one during the injection. Although his illustrations were poor, it was apparent that he had succeeded for the first time in demonstrating the ascending human aorta (Fig. 10.11)\textsuperscript{78}. Almost a decade later, in 1945, Radner reported studies in five patients using the direct puncture technique, and since that time a number of other reports have appeared.\textsuperscript{79}

In 1939 Castellanos and Pereiras described the method of retrograde brachial aortography.\textsuperscript{80} As so often happens, they had come upon the method by chance. Believing they were injecting contrast agent into the femoral vein, they discovered following the injection that the trocar was in the femoral artery and that the contrast agent had passed retrograde as far as the mid thoracic aorta. Subsequently, again without design, the brachial artery was injected, and the entire aortic arch was visualized. The potential for diagnosing patent ductus arteriosus and coarctation of the aorta became immediately apparent and was illustrated by Castellanos and Pereiras (Fig. 10.12). A decade after the first report of its use, Keith and Forsyth re-emphasized its value in studying infants with heart failure.\textsuperscript{81} In 1948 Stephens and Freeman initially reported on the use of retrograde carotid aortography, and almost simultaneously Burford and Carson used the method to obtain excellent studies of patent ductus arteriosus and coarctation of the aorta.\textsuperscript{82,83}

Roushöö, who first utilized direct puncture in animals, also employed catheter injection in 1939.\textsuperscript{84} It was Sig Radner who first applied the catheter method to thoracic aortography in clinical subjects.\textsuperscript{85} He exposed the radial artery on the right or left side and introduced a size seven to nine catheter into the artery. This was passed in retrograde direction and under fluoroscopic control via the brachial, axillary, and subclavian arteries into the ascending aorta. After the catheter tip was in the desired position, the injection was made. This method was used by Jönsson and his colleagues in the study of patent ductus arteriosus and coarctation of the aorta.\textsuperscript{86} With the introduc-
tion of the percutaneous transfemoral catheterization technique in 1953 by Sven Sellinger, the modern method of thoracic aortography became well established.\(^7\)

Left ventricular puncture as a means of opacifying the aorta was first performed by Nuvoli in 1936.\(^8\) Others took up the method, but it is no longer in use.

Thus, thoracic aortography as a technique that is now widely used, although CT and MR have replaced it for some important diagnostic problems.

**Coronary Arteriography**

Coronary arteriography began with the elegant anticipatory studies of Rousshöi (Fig. 10.13) and of Reboul and Racine, each of whose investigations demonstrated the coronary arteries in animals.\(^8\) It was not until 1948, however, that Gunnar Jönsson’s paper showed that bolus root aortography could opacify the coronary arteries in humans (Fig. 10.14).\(^9\) DiGuglielmo and Guttadauro published a monograph on the subject in 1952 based on their work in Jönsson’s department.\(^9\) Balloon occlusion of the aorta or inferior vena cava was employed by Dotter and Frisch to permit a longer perfusion of the coronary arteries.\(^9\) Mason Sones in 1959 began to do semi-selective studies, injecting in the aortic sinuses near the coronary ostia, and subsequently used selective injection via brachial cutdown. In 1962 he reported his success with the selective method in detail (Fig. 10.15).\(^9\)

In 1961 Ricketts and Abrams first performed percutaneous transfemoral selective coronary arteriography with preshaped catheters.\(^9\) Five years later modifications of this technique were developed.\(^6\) Judkins used newer thermoplastic material to design catheters widely used today for coronary arteriography.\(^7\) Meanwhile, Paulin in 1964 published his study based on loop bolus injections, relating arteriographic findings to the clinical and electrocardiographic data.\(^8\)

No sophisticated surgery has ever been able to develop in twentieth-century medicine without a preceding

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Fig. 10.13 Aortography performed in animals by Rousshöi, demonstrating the coronary arteries well opacified (1933). (Reprinted with permission from Acta Radiologica)

Fig. 10.14 The first description in human subjects of coronary visualization achieved by bolus injection into the root of the aorta. (Reprinted with permission from Acta Radiologica)

Fig. 10.15 The first published article by Sones describing selective coronary arteriography via the brachial cutdown route. (Author’s collection)
Percutaneous Selective Coronary Cine Arteriography

Howard J. Ricketts, M.D., and Herbert L. Abrams, M.D., Palo Alto, Calif.

Diagnostic Visualization of the coronary arteries in vivo has been accented by a variety of methods, both in the medical literature and in practice. Sophisticated radiology to provide a road map. This is as true of surgery of the brain, lungs, gastrointestinal tract, kidneys, and bone as it is of the cardiovascular system. By the time open heart surgery became feasible in the mid-1950s, angiography had graduated from the status of an experimental investigative procedure with little clinical applicability to a highly refined diagnostic method. It was therefore possible to put it to use rapidly to provide the kind of morphologic information for the surgeon which was essential not only to successful surgery at the time, but to the development of new methods of handling more and more complicated lesions.

Improvements in angiography have been designed to decrease the dangers and improve the quality of the studies. In the 1960s and late 1970s great strides were made in the quality of image amplification, particularly with the introduction of the cesium iodide tube. Simultaneously, powerful generators were developed, capable of millisecond exposures and high contrast levels. The cine cameras evolved into dependable instruments with line quality lenses, so that the resolution of modern 35-millimeter cineangiography is extraordinarily good (Fig. 10.16). Video recording techniques improved strikingly. Instantaneous playback of tape-recorded images has afforded great utility and safety in determining whether the desired anatomic and physiologic information has been attained, thereby precluding additional unnecessary studies.

An important technical innovation was the introduction of angled views for the study of congenital and acquired heart disease. The equipment companies responded to this innovation with engineering advances which made angled views relatively simple. The C arm, the U arm, and the parallelogram have all contributed immensely to our
capacity to attain angled images without excessive time or patient movement (Fig. 10.17).

A major advance in angiocardiology has involved the analysis of ventricular wall motion and behavior in coronary disease from a qualitative point of view. This has allowed an evaluation of regional contractility and therefore of muscle loss. The definition of ventricular aneurysm has also changed. It is now variously described as “a circumscribed outpouching of the left ventricle” or an area of akinesis or dyskinesis.100,101

Angiocardiography has also been employed to derive vital quantitative information related to ventricular function, including ventricular volumes, left ventricular wall mass, and a great deal of other physiologic data.

**INTERVENTIONAL ANGIOCARDIOGRAPHY**

A far-reaching development has been the application of the angiographic catheter to the nonoperative therapy of congenital and acquired heart disease. These advances have come about through the extraordinary ingenuity of a number of individuals who have utilized conventional catheter technology, refined it significantly, and demonstrated its value in specific applications. Closure of patent ductus by the method of Portmann, atrial septal closure, atrial septostomy, and balloon dilatation of coarctation and pulmonary valvotomy are all components of this innovation.102,103,104,105

CT demonstrated its efficacy in cross-sectional imaging of the heart, but it has largely been supplanted by MR. MR is playing an increasingly important role in the evaluation of the heart and great vessels. It is already an established technique for the evaluation of congenital heart disease, cardiac tumors, and disorders of the aorta and pericardium. Using fast scanning and a cine format, MR can evaluate ventricular function and the regurgitation of blood across heart valves.

Echo and radionuclide scanning, beyond the scope of this brief history (with PET and SPECT making their own contributions), are important methods of cardiac imaging.

**CONCLUSION**

There are times in medicine when we tend to forget. In particular, techniques which have become an integral part of the standard armamentarium of diagnosis and therapy are passed on to each new generation of physicians or trainees without any sense of the efforts involved in their initial development.

How remarkable, then, to get back to the beginnings. How much more complete our understanding as we trace the struggles of the pioneers in the field who faced the problems with intelligence and acumen. It is perspective which is so often lacking in contemporary life; more often the secret of placing contemporary events and medicine in an appropriate framework lies in familiarity with the historic past.

It is fair to say that the pioneers of radiology of the heart, from Williams in 1896 to Forssmann in 1928 to Castellanos in 1937, would be astonished at how far the field has come and how much information is attainable on the structure and function of the heart from diagnostic imaging. Such information has allowed us to follow the course and biology of heart disease in a single patient over decades, depicting as it does overall changes in size and shape of the heart, the chambers, and the great vessels; to provide a road map for the cardiac surgeon in complex congenital anomalies and acquired heart disease, without which the era of open heart surgery could never have advanced so rapidly and so well; and to depict with extraordinary precision the status of coronary arteries and the appropriateness of coronary bypass surgery or angioplasty, as well as their effectiveness.

A century is a short time in the history of medicine and man; for cardiac radiology, it has been an eventful one.
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