DIALOGUES

DIAGNOSTIC CARDIOLOGY: from a tap on the chest to viewing the heart in three dimensions

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Attempts at cardiac diagnosis go back to antiquity, but until the 18th century not much progress was made. The invention of the stethoscope and the development of instrumental methods in the 19th century catalyzed cardiac investigation and led to recording of venous and arterial pulse records from 1880 onwards. Heart sound recording started in 1900, and phonocardiography was used for about 60 years and then faded. Roentgen's discovery of x-rays in 1895 was the start of a huge technological development in radiology, which is still continuing. Echocardiography and radiology have transformed cardiac diagnosis, though with a deleterious effect on clinical examination. The future is bright for further technological development, though the patient's history will remain a keystone in diagnosis, providing physicians remember its importance.

Keywords: history; physical examination; kymograph; clinical polygraph; stethoscope; phonocardiography; radiology; apex beat recording; computed tomography; magnetic resonance imaging

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Nowadays, when technology seems to reign supreme—and, like the fruit on a tree tends to monopolize our attention—it is good to remember that clinical skills can be the best diagnostic method. In particular, the history of the illness may be the only clue to a puzzling diagnosis. "Listen to the patient and he will give you the answer." This is advice that medical students, formerly including myself, have never really accepted from their teachers, believing that a laboratory method must be the best. In other words, we overlooked the roots, without which the tree would not exist. The symbol of the tree, which serves as a leitmotiv throughout this issue of *Dialogues*—and which, as a dedicated botanist, is one that greatly appeals to me—is particularly relevant in the realm of diagnosis: no part of the tree is independent of the rest and, although pruning is necessary, and even mandatory, as each new stage in the growth of the tree takes place, never does a more recent stage supersede the earlier ones.

CARDIAC EXAMINATION

Physical examination is of great value by itself, but also because it points the way to other modes of investigation. Percussion of the chest was invented in 1761 by Leopold Auenbrugger in Austria, inspired by his father, an innkeeper, who would tap his oaken casks to estimate the quantity of wine they contained. Auenbrugger first used percussion in a case of pericardial effusion, and his method was popularized by Jean Nicolas Corvisart in France in 1806. In 1828, Pierre-Adolphe Piorry invented the pleximeter—an ivory plaque placed on the chest and struck with a finger. Medical students were taught to carefully percuss the borders of the heart up to about 1950, but John Parkinson had already shown that radiology was the only reliable way of determining cardiac size.[1] Percussion of the heart is now rarely used. By contrast, the jugular venous pulse and pressure have stood the test of time, even if some doctors now neglect to look at them. The venous pulse of tricuspid incompetence was described by Giovanni Maria Lancisi as far back at 1745, and the findings in various arrhythmias were well known 100 years ago. In 1933, Thomas Lewis introduced the standard method of assessing right heart failure by measurement of the height of the jugular venous pressure above the sternal angle.[2]

CARDIAC AUSCULTATION

The stethoscope remains the symbol of the doctor in the eye of the public. Early in the 19th century, some French physicians such as Jean Nicolas Corvisart used the *immediate* method of listening to the heart with an ear applied directly to the chest, that is, almost directly, for sometimes a piece of fine cloth was interposed between the doctor's ear and the patient's chest. On September 13, 1816 René Théophile Hyacinthe Laennec, then aged 35, while on a ward round at the Hôpital Necker in Paris, decided, as he said to "avail ourselves of the use which acoustics yields to us," and having rolled up the *cahier de visite* of a student, he applied that cylinder of paper to the chest. Thus was born *mediate* auscultation and the momentous invention of the stethoscope. Laennec soon replaced the roll of paper, and a roll of pasted cardboard, by his famous wooden cylinder, which itself soon became modified by himself and others. Others such as James Hope in England and Austin Flint in America soon adopted this method, helped by Sir John Forbes' translation in 1821 of Laennec's 1819 book *De L'Auscultation Médiate.*

However, the monaural model was not ideal and indeed it was described by an American doctor as "the objectionable European instrument."[3] Nevertheless, its many modifications persisted for nearly one hundred years and as late as 1912 an instrument catalog showed 78 monaural types. A variety of monaural stethoscope is still used today in some countries by obstetricians and midwives.

Naturally, however, there was an early desire to produce a binaural instrument, and Charles James Blasius Williams of London made the first one in 1829 using two bent lead pipes. Progress depended on getting flexible material for the tubing and before vulcanization of rubber was achieved in 1839, there were two other plant substances available, namely, gutta-percha (from the milky juice of trees of the *Palaguium* and *Payena* genera, Sapotaceae family), and untreated rubber (from the milky juice of *Hevea brasiliensis* and other species, Euphorbiaceae family), called caoutchouc (from the Quechua *kawchu*) or gum elastic. In 1841, William Stroud led the way by covering a coiled wire tube with

Figure 1. *The 1855 binaural stethoscope of George Camman. Reproduced with permission from M. D. Blaufox.*

Reproduced from reference 3: *Blaufox MD.* An Ear to the Chest. An Illustrated History of the Evolution of the Stethoscope. *London, UK: Parthenon; 2002. Copyright © 2002, Parthenon.*

silk impregnated with caoutchouc, and Arthur Leared of London made a molded binaural model in 1851 from gutta-percha. But the first truly practical binaural device was that of George P. Camman of New York in 1855. It had a bell-shaped chest piece joined to the two earpieces by tubes of gum elastic and even had a spring to hold the earpieces snugly together. *(Figure 1)*.[3] By 1912, there were 53 types of binaural models, including that of S. Scott Alison, which had two chest pieces allowing sound from two different areas to be heard at the same time!

The most thoughtful change of design was the invention of the diaphragm chest piece in 1894 by Robert C. M. Bowles of Brookline, Massachusetts, which enhanced the perception of high-pitched murmurs. It was left to Howard B. Sprague of Boston to introduce the final modification by combining a diaphragm and a bell into one chest piece in 1926. Rather surprisingly, some experts in heart sounds and murmurs such as the late Samuel Levine of Boston continued to use only the bell type. Subsequent designs included that of Aubrey Leatham of London, in 1955, whose model had a bell with two components, large and small, and also the current Littmann model. This article is on methods not results, but it can be briefly mentioned that keen auscultators soon identified new sounds and murmurs. Pierre Carl Édouard Potain in Paris described the "bruit de galop"—our atrial or fourth heart sound—in 1876, and Alexander Gibson in Oxford the third sound in 1907. Then there were the eponymous diastolic murmurs of Austin Flint in 1862, Henri Roger in 1879, and Graham Steell in 1886. Enthusiasm for murmurs grew to the point where they became almost the sole criterion in prognosis and in 1908 Sir James Mackenzie wrote, "I sometimes wonder whether the use of auscultation has not been the means of doing more harm than good."[4]

PHONOCARDIOGRAPHY

There was a natural desire to record the fascinating noises heard through the stethoscope and using Gabriel Lippmann's capillary electrometer Willem Einthoven of Leiden was the first to do this in 1896. He later used his string galvanometer with better results, as did Thomas Lewis, who produced good quality recordings of sounds and murmurs *(Fig-*

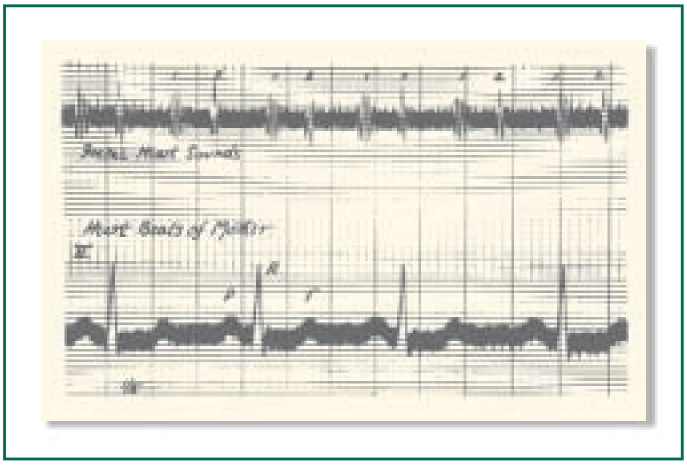

Figure 2. *Phonocardiogram of fetus with simultaneous electrocardiogram of the mother, performed by Thomas Lewis in 1913. Lewis was the first to make twin channel photographic recordings using the twin-string galvanometer of the Cambridge Instrument Company. Courtesy of Arthur Hollman.*

ure 2).[2] The introduction of filtration into the amplifying system by M. B. Rappaport and Howard B. Sprague in America in 1941 made it easier to analyze sounds and murmurs and these workers delineated the physical and physiological laws governing auscultation. In the 1950s, Alfredo Luisada in Chicago was a great pioneer, as was Aubrey Leatham in London.[5] A different look was provided in Baltimore by Victor McKusick, who invented the spectral phonocardiogram, whereby murmurs were recorded according to their frequency range and intensity. Five monographs on phonocardiography appeared in the 20th century, from 1911 to 1963. However, now, in 2005, the method is virtually obsolete and clinicians are no longer interested in checking their auscultatory findings.

GRAPHIC REGISTRATION

Scientific investigation of the cardiovascular system started in 1628 with the experimental work of William Harvey, but it was not until the 19th century that recording methods were developed and at first these were done, as one might expect, by animal physiologists.

The invention of the rotating drum recorder, the kymograph (wave recorder) in 1846 by Karl Ludwig was an essential start, and its potential was built upon by Étienne Jules Marey in Paris, who recorded the intracardiac pressures in horses using a kymograph with pen recorders.[6] Marey is an important figure in the history of cardiology, for by modifying his instruments so that they were applicable to humans, he was largely responsible for the introduction of investigational techniques on which modern cardiology is based.[4] In 1859, he invented a sphygmograph (pulse recorder), which he strapped to the patient's arm to record the arterial pulse. Recordings with various instruments were often made onto paper with a deposit of soot which was removed by a stylus giving a white line—the smoked paper recording, made permanent with a coating of varnish. This was the method used in 1882 in the sphygmograph of Robert Ellis Dudgeon. This small instrument strapped easily onto the radial artery at the wrist and it became the preferred method for recording the arterial pulse, analyzing not only the rhythm, but also waveform. And then came a decisive moment in cardiac investigation when James Mackenzie invented his clinical polygraph in 1890. He modified the Dudgeon sphygmograph by using a second stylus connected to a tambour, which allowed the jugular venous pulse, or the apex beat, to

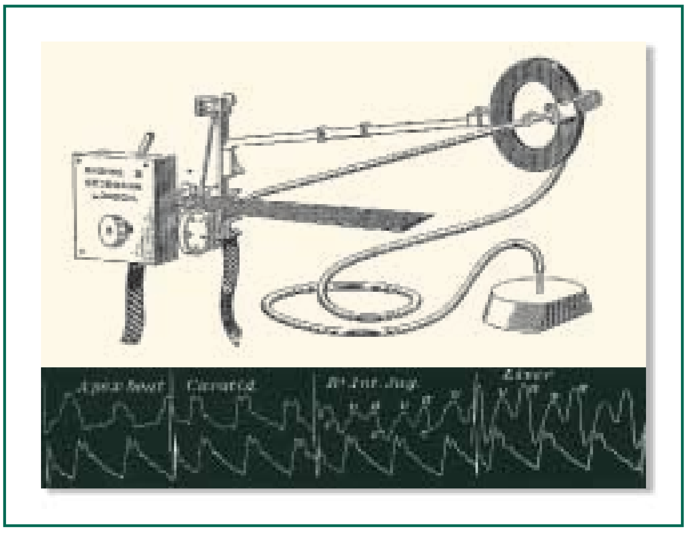

Figure 3. *The 1892 clinical polygraph of James Mackenzie, with recordings of the apex beat, carotid pulse, jugular venous pulse, and hepatic pulsation above the radial pulse, a technically difficult procedure.*

Reproduced from reference 8: *Mackenzie J.* The Study of the Pulse Arterial Venous and Hepatic and of the Movements of the Heart. *Edinburgh, UK: Y. J. Pentland; 1902:10, 13. Copyright © Y. J. Pentland.*

be recorded at the same time as the radial pulse *(Figure 3)*.[7,8] In other words, one could simultaneously record events from the right and left heart. Using this device, Mackenzie showed the essential feature of what was later proved to be atrial fibrillation *(Figure 4)*.[8] Smoked paper was awkward to use, and in 1906 Mackenzie invented an ink-writing polygraph, which was redesigned by Thomas Lewis in 1914. The Mackenzie-Lewis polygraph was portable and easy to use and it was widely used to elucidate arrhythmias even after the electrocardiogram had become established. For example, it recorded very well the large a waves of junctional tachycardia. The next step in recording mechanical events was with photographic recording, which was first done quite simply by placing the stylus of, say, a venous pulse tambour, in the beam of light of an electrocardiograph. From 1911 to 1915, Thomas Lewis used this method for his experimental studies on dogs with recordings from the atria and ventricles.[2] But it is Otto Frank of Munich who has the credit for introducing precise optical recordings of pressure pulses, a method taken up in the USA by Carl Wiggers. Crighton Bramwell in Manchester used cathode-ray recording in the 1930s, but this never became popular. After the 1950s, electronic recording devices made it possible to record mechanical events with ease and precision, using the hot stylus method, which was best developed by the Sanborn Company in the USA. An ingenious method that was developed in Sweden by Carl Hellmuth Hertz and R. Elmqvist was the ink-jet recorder, which overcame the problem of friction by the stylus on the paper. It was called a Mingograph, from the Latin "to pass water," literally a urinating apparatus! It was also good for phonocardiography.

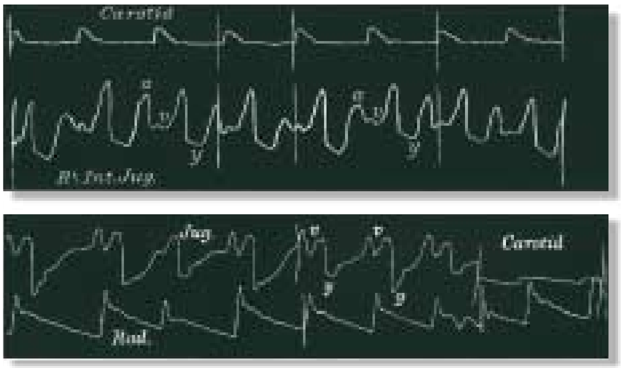

Figure 4. *Jugular venous pulse tracings taken from the same patient in 1898 showing in the lower tracing that the atrial wave,* **a** *, disappears when the cardiac rhythm becomes completely irregular. Mackenzie wrote, "I have not the slightest doubt that there was a temporary paralysis of the auricle" and a few years later the electrocardiogram proved the rhythm to be atrial fibrillation. This is a seminal recording in the history of cardiology. It was the first proof of the mechanism of "pulsus irregularis perpetuus," which had eluded many others.*

Reproduced from reference 8: *Mackenzie J.* The Study of the Pulse Arterial Venous and Hepatic and of the Movements of the Heart. *Edinburgh, UK: Y. J. Pentland; 1902:10, 13. Copyright © Y. J. Pentland.*

PULSE MEASUREMENT AND RECORDING

Examination of the pulse was practiced from the very earliest times and was known to the Chinese in 2700 BC (the *Huangdi Neijing, Nanjing,* and *Maijing* canons of medicine) and to the ancient Egyptians (as recounted in the Edwin Smith papyrus of around 3000 BC). Claudius Galen, whose writings dominated medicine for centuries, wrote 18 books on the pulse around AD 180 and, for example, his pulsus caprisans had a double impulse like the leap of a goat, and probably was a dicrotic pulse.[4] However, finding a method to measure the rate of the pulse proved a difficult problem, and various so-called water clocks from Egyptian and Roman times were not satisfactory. The first solution was Galilei Galileo's invention of a pendulum-driven device called a pulsilogium, in about 1580.[6] Although spring-driven watches were available around 1600 or earlier, they measured only hours, but in 1707 Sir John Floyer invented his pulse watch, which ran for 60 seconds only. By the 19th century, there was no problem in measuring the pulse rate and more attention was paid to pulse abnormalities and to their recording. The sphygmograph of Karl Vierordt in 1855, which preceded Marey's work, was used by him to record pulsus paradoxus in a patient with pericarditis.[4] Clinicians described important pulse abnormalities even if they did not record them, a notable example being the collapsing pulse of aortic incompetence of Dominic John Corrigan in Dublin in 1832. But observation was not enough for Thomas Lewis, the clinical scientist, and in 1906 he undertook experiments on the mechanism of the dicrotic pulse. In patients undergoing a venesection, he showed how volume depletion caused the pulse to become dicrotic. And in the laboratory, he had a reservoir system connected to a tambour with a sphygmograph mounted on its surface, and produced dicrotism with artificial volume changes.[2]

APEX CARDIOGRAPHY

William Harvey had noted how the apex of the heart rises up and strikes the chest wall producing the apex beat and, in the 19th century, various investigators turned their attention to this clinical sign. Foremost was Étienne Jules Marey who made recordings of the apexcardiogram; a debate with Joseph Honoré Simon Beau about their significance led him to make the first-ever intracardiac recordings. This was carried out in horses using balloon-tipped catheters in the right and left ventricles in 1861.[6] Pierre Carl Édouard Potain in Paris, in 1875, used apex recordings with simultaneous venous and arterial tracings and James Mackenzie, in 1902, showed that the apex beat retracted with right ventricular hypertrophy. In recent times J. L. Willems in Holland introduced the term mechanocardiography to encompass all recordings of cardiac and vascular pulsations. Apex beat recordings were promoted by E. Grey Dimond in the 1960s and although they have never been widely adopted it is quite likely that their diagnostic value has been underrecognized For example, Peter Nixon used a linear displacement transducer to obtain precise recordings and he studied the position of the atrial beat on the left ventricular apex tracing.[9] When there was left ventricular failure, the atrial impulse climbed the higher on the upstroke of the curve the worse the failure *(Figure 5)*.[9]

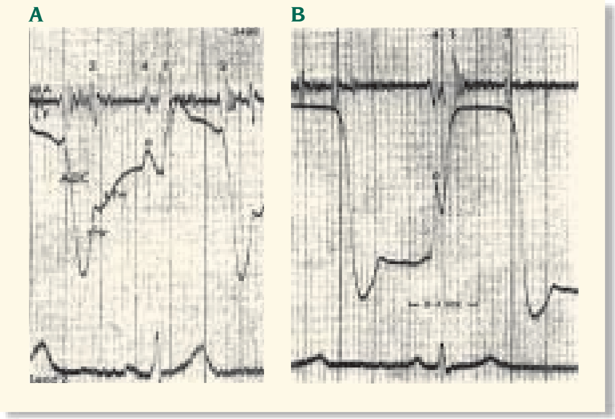

Figure 5. *Apex cardiograms.* ***A*** *normal;* ***B*** *coronary heart disease, showing in* ***B*** *that atrial systole, a, is now on the upstroke of the apex beat, with a loud 4th sound in the phonocardiogram above. Also in* ***B*** *the rapid filling wave (rfw in* ***A****) is attenuated.*

Reproduced from reference 9: *Bethell HJN, Nixon PGF. Understanding the atrial sound.* Br Heart J. *1973;35:229-235. Copyright © 1973, BMJ Publishing Group, Ltd.*

BALLISTO-CARDIOGRAPHY

This method was a recording of the recoil of the body as a whole as a result of the ejection of blood from the heart, and the idea behind it was the attractive one of being able to record the force of contraction of the left ventricle and also the stroke volume. It was Isaac Starr in the USA who promoted this method from 1939 onwards and he was followed in the 1950s by William Dock in New York.[4] It was said that coronary heart disease produced a special wave in the tracing. But this technique was never proven to be of value and it was discarded.

RADIOLOGY

The discovery of x-rays by Wilhelm Conrad Roentgen in 1895 created a sensation in the scientific world. Within one year, nearly 100 papers were published on this new type of radiation. Roentgen had produced an image on a photographic plate, and, as early as 1896, Francis Henry Williams in Boston, USA, wrote, "the pulsations of the heart may be followed with the fluoroscope, not only ventricular, but also auricular contractions and dilatations."[4] His book, *The Roentgen Rays in Medicine and Surgery,* was a landmark text in 1901. Fluoroscopy became the accepted method of cardiac examination, and a particular method of doing it gained favor. This was the orthodiagram, invented by Friedrich Moritz in Munich, in which a central beam of rays was moved around the cardiac margins, allowing the outline of the heart and aorta to be drawn onto the fluoroscopic screen and then traced onto a sheet of paper *(Figure 6)*.[1,10] In 1916, Kodak was able to replace the cumbersome glass plate with photographic film, which made heart x-rays easier to process. Previously it had been said that the plate might show little beyond the finger marks of the radiographer. In 1924, H. Assmann of Leipzig wrote one of the earliest books on cardiac radiology, followed in America in 1937 by Hugo Roesler's *Clinical Roentgenology of the Cardiovascular System,* while Charles Laubry in Paris published a large text in 1939.[4] In many cardiac clinics it became a routine for all the patients to be examined under the fluoroscope at the end of the session, viewing the cardiac silhouette from three aspects and outlining the esophagus with barium to show the left atrium. Primitive "screening" apparatus would spit and hiss, and much radiation was scattered. This method also gave information about the pulmonary circulation, such as the "hilar dance" pulsations seen with a left-to-right shunt in atrial septal defect. Fluoroscopy proved of great importance when Helen Taussig at Johns Hopkins Hospital used it as her prime method of examination in congenital heart disease. The oligemic underfilled lungs in tetralogy of Fallot guided her to devise the famous Blalock-Taussig operation of 1944 *(Figure 7)*.[11]

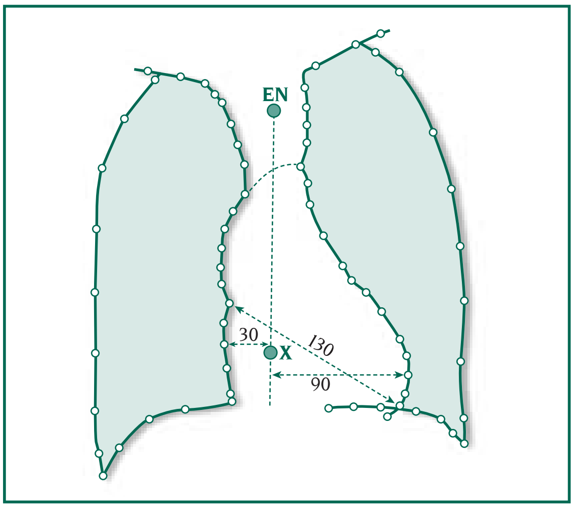

Figure 6. *Orthodiagram of the chest showing the outline of the heart and great vessels.*

Reproduced from reference 10: *Lewis T. Material relating to coarctation of the aorta of the adult type.* Heart. *1933;16:205-261. Copyright © 1933, BMJ Publishing Group, Ltd.*

An interesting approach to record cardiac pulsations was the technique of kymography in which x-rays were passed through the chest to a film that moved at a constant rate behind a grid of lead strips. This produced a jagged outline to the cardiac silhouette showing movement or lack of it. This method was soon abandoned and forgotten.[4]

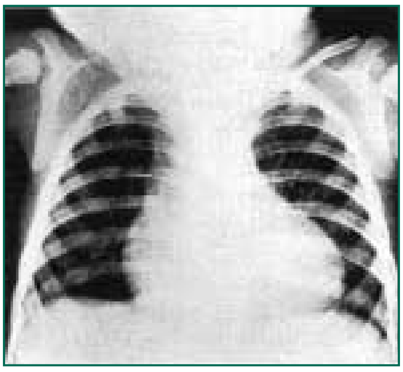

Figure 7. *Chest radiograph of an infant with tetralogy of Fallot.*

Reproduced from reference 11: *Taussig H.* Congenital Malformations of the Heart. *New York, NY: Commonwealth Fund; 1947:120. Copyright © 1947, Commonwealth Fund.*

Improvement in x-ray generators allowed teleradiography to become a practical proposition in the 1930s after its first description in 1905. The distance from the tube to the chest had to be at least 6 feet to minimize distortion, and it is now the current standard chest radiograph. Good quality chest x-rays showed not only interesting cardiac silhouettes such as that in 1933 of coarctation of the aorta, but also the changes in the lung fields from heart failure, notably perhaps the B lines of Peter Kerley, also described in 1933.[1]

The chest radiograph has the great merit of being readily available almost everywhere as it is easy to perform with basic x-ray equipment, and although it owes nothing to modern technology it remains a standard method of investigation.

ECHOCARDIOGRAPHY

Like other instrumental methods, the diagnostic use of ultrasound had a long gestation. This method is based on the piezoelectric principle, which was described in France by Jacques and Pierre Curie in 1880. The sinking of the Titanic in 1912 led E. G. Richardson in Britain to have the idea of using a beam of underwater sound to detect icebergs, and then in 1917 Paul Langevin in France made a piezoelectric generator for submarine detection. It was found that ultrasound could be transmitted through many substances and that echoes were reflected back at interfaces having different acoustic impedance. The earliest ultrasound method was the A scan, and it was used in 1929 by S. Y. Sokolov in Russia to detect flaws in metal, while his attempt to examine the cerebral ventricles was the first medical application of ultrasound. In 1941, F. A. Firestone in the USA patented an ultrasonic metal flaw detection technique and it was this method that led indirectly to the modern development of cardiac ultrasound by a German physicist, Carl Hellmuth Hertz, in Lund, Sweden, in 1953. He borrowed an ultrasonoscope from a shipyard and together with the cardiologist Inge Edler echoes were recorded from Dr Hertz's heart. Thus was modern echocardiography born. They modified the device calling it "an ultrasound reflectoscope" and used it in 1954 to show the features of mitral stenosis, including the changes before and after mitral valvotomy *(Figure 8, next page)*.[12]

They were also responsible for the M-mode display format, which provides a graphic display showing variations of position with time—something vital for cardiology. In Lund, in 1960, I saw a remarkably elegant study when an echocardiogram of the anterior leaflet of the mitral valve was recorded with a simultaneous left atrial pressure tracing. The latter was done by Stig Radner using his suprasternal nee-

Figure 8. *A historic echocardiogram showing for the first time the movements [E to F] of the anterior cusp of the mitral valve before (left) and after (right) mitral valvotomy.*

Reproduced from reference 12: *Edler I, Gustafson A. Ultrasonic cardiogram in mitral stenosis.* Acta Med Scand. *1957;159:85-90. Copyright © 1957, Almqvist and Wiksell.*

dle puncture technique. The use of cardiac ultrasound was essentially a European development. In 1957, S. Effert in Germany emphasized its value and showed masses in the left atrium. On the whole, however, its potential achieved slow recognition in spite of the fact that leading cardiologists were shown the technique.

The first clinical studies in the USA were carried out in 1963 by H. Reid and C. Joyner and it was also in 1963 that Harvey Feigenbaum started his seminal work. Employing an apparatus used by neurologists at his hospital, he was able to show pericardial effusions and it he who first used the term echocardiography. Feigenbaum trained young physicians in the method and his book *Echocardiography*, which was first published in 1972, became an essential text on the subject.[13] Advances such as "compound B scanning" in the mid 1960s gave good results in internal medicine, but not for the heart, and a major breakthrough came in 1972 when N. Bom in Rotterdam invented the linear array scanner, which produced real-time images. Shortly afterwards, J. M. Griffith and W. L. Henry in Washington introduced the mechanical "a sector" scanner. J. Somer in Holland described a multicrystal ultrasound equivalent of the "phased array radar scanner" used for missile tracking, while F. L. Thurstone and O. T. von Ramm in the USA turned this into a reality for cardiology. Almost all cardiac scanners in use today employ this technology.

Then came a quite different use of reflected ultrasound, which relied on the fact that ultrasound that is reflected from a moving target has its frequency altered by the Doppler effect. This was first used to detect moving structures in the heart by S. Satomura in Japan in 1957, and the method was further developed by D. Baker in the USA, G. Peronneau in France, and P. Wells in the UK. In 1978, Liv Hatle and her colleagues in Norway showed how continuous-wave Doppler could quantify pressure gradients across valves. It also shows the abnormal blood flow in the turbulent jets created by valvular regurgitation and intracardiac shunts. Around 1985, Kasai in Japan developed the first real-time color scanner.[14]

A new approach to cardiac echo was pioneered in Japan in 1977 by K. Hisanaga who introduced transesophageal echocardiography, making use of the fact that the left atrium is in close contact with the esophagus. This technique relied on the development of high-frequency phased array transducers. It has been useful in searching for causes of systemic emboli by finding a left atrial thrombus or a tumor, and by showing a patent foramen ovale. A modern echo machine provides all the modalities of echocardiography, and while continuous-wave Doppler can measure pressure gradients and the pulmonary artery pressure, it is pulsed Doppler that will estimate the size of an intracardiac shunt.[15] The practice of pediatric cardiology has been literally transformed by echocardiography, and now, to give just one example, sick neonates can be evaluated without the need for emergency catheterization—and midnight surgery. Intrauterine echo studies of the fetus can show even complex congenital lesions at an early stage of pregnancy.

Although echocardiography has revolutionized clinical diagnosis and management across the board, it has also advanced our knowledge of cardiac physiology. D. G. Gibson used M-mode echocardiography to perform sophisticated studies of left ventricular function in health and disease, while Graham Leech and Aubrey Leatham used simultaneous phonocardiograms and echocardiograms to elucidate the mechanism of the first heart sound.

The information from echocardiography in its various modes is so comprehensive that it has led to a diminished respect for the traditional methods of cardiac diagnosis. However, these still have an important role in asking what questions the echocardiograph is required to answer. In many countries it is the highly skilled technical staff that perform most of the examinations, and the role of the cardiac ultrasonographer needs strong emphasis and applause for the excellence of their work.

MODERN DIAGNOSTIC METHODS

Computed tomography (CT)

Computed tomography (CT) of x-ray images was the brilliant invention of Godfrey Hounsfield in Britain in 1972. The mathematics were so involved that some big organizations, having thought about the idea, decided that it was too difficult to pursue. At first, image acquisition was too slow to permit examination of the heart, but the development of multidetector CT in 1999 produced excellent results and permits the heart to be viewed in three dimensions. Currently, the main uses of cardiac CT are for coronary artery calcium scanning and CT coronary angiography. High calcium scores can predict an increased incidence of adverse coronary events, even up to a 22-fold increase. After intravenous contrast, the images of the coronary arteries are very good, down to a resolution of 0.5 mm. Compared with catheter angiography, there is a sensitivity of 92% to 95% and a specificity of 86% to 93%.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) uses large magnets and radio frequency waves to produce high-quality still and moving pictures of the body's internal structures. It was invented by Paul Lauterbur in the USA and Peter Mansfield in Britain, starting in 1973. MRI acquires information about the heart as it is beating and can display abnormalities in cardiac chamber contraction and show abnormal patterns of blood flow. After a bolus of gadolinium, it is possible to assess myocardial perfusion on a semiquantitative basis. Cardiac MRI has been widely used for perfusion studies and for the evaluation of congenital heart disease.[16]

Radionuclide imaging

Radionuclide imaging was first used a long time ago when H. L. Blumgart and P. Weiss in 1937 injected radium C intravenously to measure the circulation time. In 1948, S. S. Kety used radioactive sodium to determine blood flow in the myocardium. Development of modern imaging devices by A. M. Rejali in 1958 and H. O. Anger in 1963 promoted the use of radionuclide diagnosis. With thallium 201 and newer compounds, this method is widely used to detect areas of transient myocardial ischemia after exercise, among other applications.[17]

CONCLUSION: A BRIEF HISTORY OF DIAGNOSTIC CARDIOLOGY

The tree of cardiological diagnosis has witnessed dramatic growth since the days when diagnosis was based on a doctor's eyes, hands, and questions. Informed cardiac diagnosis could not get under way until there was good evidence of the disease process from autopsy examination—clinicopathological correlation started with Morgagni's work *De Sedibus* in 1761. This was notably continued in France in the 19th century where clinical diagnosis was born in 1819 with the invention of the stethoscope. There was an urgent need to make recordings of the beating heart and this led to the invention of the polygraph in 1882 and, importantly, in 1901, to the birth of electrocardiography, while the discovery of x-rays in 1895 gave rise to cardiac radiology. Intracardiac pressures had long been measured in animals and the introduction of cardiac catheterization in the early 1940s enabled this to be done in humans. This was soon to be followed by contrast visualization of the heart, which gave the precise diagnosis needed for open-heart surgery in congenital heart disease. Echocardiography, invented in 1953, was especially helpful for cardiac diagnosis in showing not only cardiac anatomy, but also blood flow. Being noninvasive, it proved a wonderful tool for patients, especially for infants and young children. Recent developments in multidetector computed tomography scanning and magnetic resonance imaging are already proving very useful and hold much promise for the future. Notwithstanding the dramatic achievements of all these increasingly sophisticated diagnostic tools, to paraphrase from *The Gondoliers,* there is still "no probable possible shadow of doubt" that a thorough history and physical examination are the best way to commence the diagnostic process: for all the wealth of branches and foliage we should not forget the humble but firm basis on which diagnosis—be it cardiology or any other field of medicine—is rooted: listen, look, touch.

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