Circulation
Volume 93, Issue 7, 1 April 1996; Pages 1321-1327
https://doi.org/10.1161/01.CIR.93.7.1321

ARTICLE

Evolution of Echocardiography

Harvey Feigenbaum

The word “evolution” is usually reserved for changes of natural phenomena and thus is appropriate to be used with echocardiography or diagnostic ultrasound in general. Unlike most medical diagnostic tests or procedures, diagnostic ultrasound exists in nature. Some mammals, such as bats and aquatic mammals, have the natural ability to visualize their environments sonically. The sonic imaging capability that these animals have is truly amazing. I have often equated ultrasonic instrument manufacturers with the aircraft industry. Humans have known that creatures with wings could fly. Since nature did not endow humans with wings, we had to build machines with wings so that we could fly like birds. In many ways, we are doing the same thing with diagnostic ultrasound. Nature did not see fit to give us sonic imaging capability, so we must build appropriate machines so that we can visualize ultrasonically, as other mammals do naturally.

The evolution of medical diagnostic ultrasound, and echocardiography in particular, has been dramatic, and its ultimate capabilities are still unrealized. The origins of this technology date back to Curie and Curie,[1 2] who first discovered piezoelectricity. A variety of subsequent discoveries were made that culminated in the first patent for ultrasonic, nondestructive flaw detection, issued to Sokolov in 1937.[3] Firestone[4] received a patent in 1942 for a somewhat similar device. Developments in this field accelerated quickly during World War II, when this application was used for naval sonar.

After the end of World War II, numerous investigators sought peaceful uses for wartime technology. Sonar or diagnostic ultrasound was one of many such technologies. The early devices often used crude, two-dimensional scanning techniques. There were also A-mode examinations, whereby one merely looked at the location and amplitude of the returning ultrasonic signal. Virtually every organ of the body was scrutinized.[5 6 7 8 9] Most of the early work was done by physical scientists. Very little was reported in the medical literature, and these investigations had minimal if any clinical impact for many years.

Wild[10] was probably the first of the early investigators to examine the heart ultrasonically. This work was done primarily with autopsy specimens. It is interesting that one of his coworkers was Reid, who went on to make many important contributions to the field.[11] Neither Wild nor Reid was a physician. The first physician who is credited with using ultrasound to examine the heart was Keidel.[12] He attempted to use ultrasound as we commonly use x-ray. He directed the ultrasonic beam through the chest and obtained an acoustic shadow. He had some success and noticed that the acoustic shadow would vary with changes in cardiac volume. Keidel's attempts at transmission ultrasound never became popular.

CLINICAL CARDIAC ULTRASOUND

The first use of echocardiography as we know it today is usually credited to Edler and Hertz.[13] Japanese investigators[14 15 16] were also working with ultrasound at about the same time and may or may not have been aware of what was happening in Europe. Edler was a cardiologist practicing at Lund University in Sweden and was in charge of the cardiology department of the medical clinic. Hertz, who was a physicist, had a long-standing interest in using ultrasound for the measurement of distances. It should be noted that Hertz came from a very famous family. Both his father and his uncle were internationally known physicists. One won the Nobel prize in physics and the other was the man whose name was appropriated to describe wave frequencies. Hertz was familiar with the work of Firestone, and he collaborated with Edler to see whether this technique would be useful in examining the heart. Hertz located a commercial ultrasonic reflectoscope used for nondestructive testing. The first person to be examined was himself. He identified a signal that moved with cardiac action. It was with this instrument that the field of echocardiography, using the time-motion or M-mode approach, began (Fig 1).

One of Edler's principal medical concerns in those days was mitral stenosis.[18 19] He concentrated on this application for the ultrasonic examination that he now called "ultrasound cardiography." He was able to record several signals from the heart, but identification of these echoes was difficult. He described a signal that we now know originates from the anterior leaflet of the mitral valve. However, initially he thought that this echo was coming from the back wall of the left atrium. The manner in which he discovered the true identity of this echo is interesting.[17] Edler performed ultrasonic examinations on patients who were dying. He marked the location and direction of the ultrasonic beam. When the patient died, he stuck an ice pick into the chest in the direction of the ultrasonic beam. At autopsy, he discovered that the beam transected the anterior leaflet of the mitral valve and not necessarily the back wall of the left atrium.

Edler reported several structures that he identified on the ultrasound cardiogram. He made a film that was shown at the European Congress of Cardiology in Rome in 1960.[20] In this film, he described the mitral valve with mitral stenosis and several other normal structures, such as the cardiac valves and the aorta. He noted the back wall of the left ventricle. There was also a description of a patient with a large anterior pericardial effusion. He then wrote a fairly extensive review article that appeared in *Acta Medica Scandinavia* in 1961.[17] Despite these many ultrasonic findings, the main application that he thought was practical was the detection of mitral stenosis. He relied entirely on the M-mode diastolic E-to-F slope for both the qualitative and quantitative diagnosis. He also used this measurement to help differentiate mitral stenosis from mitral regurgitation. By the early 1960s, he was no longer publishing any new work. Although he continued to write review articles, they primarily pertained to mitral stenosis and the mitral valve E-to-F slope. He eventually retired in 1976.

Hertz left the field of cardiac ultrasound fairly early. In the course of his work with Edler, he became interested in how the recordings were made. In so doing, he developed ink-jet technology. This work was very successful, and he proceeded to obtain many important patents on ink-jet recording technology. Hertz died of prostate cancer in 1989.

There were several other early European workers in the field of cardiac ultrasound. These investigators probably were stimulated by Edler's early writings. These European workers included Effert, Schmitt, and Braun.[21 22] One of Effert's notable discoveries was the identification of left atrial masses using cardiac ultrasound.[23] However, these workers seemed to lose interest in the field, and by the early 1960s, it was difficult to identify any interest in cardiac ultrasound in Europe.

The Japanese were also working in this area with or without the knowledge of what was happening in Europe. The early Japanese investigators took a different approach with ultrasound. These workers, including people such as Satomura,[14] Yoshida,[15 16] and Nimura,[15 16] were primarily interested in Doppler technology. The first Japanese publications concerning ultrasound appeared around 1955.[14]

AMERICAN EXPERIENCE

The American experience with echocardiography began with Reid, who earlier worked with Wild. Reid went to the University of Pennsylvania as a graduate student. He wanted to pursue his interest in diagnostic ultrasound. He teamed up with Joyner, who was a cardiologist at the university. Reid proceeded to build an ultrasonic reflectoscope. He then worked with Joyner to repeat the work that Edler had done with mitral stenosis. This effort culminated in a manuscript published in *Circulation* in 1963[24] that represents the first American article on the cardiac use of diagnostic ultrasound. Reid later developed many important engineering advances in ultrasound, especially with Doppler techniques.

My own involvement with cardiac ultrasound is a classic example of a fortuitous event that literally changed my life. In 1963, I was working in the cardiac catheterization laboratory. My investigational interest was in studying left ventricular diastolic function or compliance. I was using catheterization techniques for measuring output, volumes, and pressures. I was frustrated with the tediousness and inaccuracies inherent in these techniques. As is my common practice, I usually eat lunch in my office and read "throw-away literature." In one of these throw-away journals, I noticed an advertisement by a company making ultrasound instruments. The advertisement claimed that there was an instrument that could measure instantaneous cardiac volumes with ultrasound. I called the company. The person who answered the phone informed me that they were going to display this instrument at the upcoming American Heart Association meeting, which was in Los Angeles that year, and I arranged to see it there.

When I went to the booth where the instrument was being displayed, it became apparent that the advertisement was totally false. The people at the booth had absolutely no idea how their instrument could possibly measure cardiac volume. Instead of turning away in disgust, I asked the person displaying the equipment to tell me a little bit about the instrument. I proceeded to take the ultrasonic transducer and place it on my chest. I was able to find a signal that I found fascinating. This was likely the same echo that Hertz saw about 10 years earlier. The salesman had no idea what this signal represented. By assessing the way the signal was moving and by checking my own pulse, I judged that the signal had to be coming from the back wall of the left ventricle. I asked the salesman how such a signal could be produced. He told me that there must be an interface with different acoustic properties, such as density. I asked what would happen if there were fluid in the area of the back wall of the left ventricle. He said that the fluid should be free of any echoes. I then asked the salesman if this instrument could be used to detect pericardial effusion. I don’t think he knew what pericardial effusion was.

When I returned to Indiana, I learned that the neurologists had an ultrasound instrument that they were using to detect the midline of the brain. I went to see the equipment and noticed that it was not being used. I borrowed the instrument and proceeded to try to find the signal I had noted in Los Angeles. This echo was indeed easily found, and with additional experience, I was convinced that this signal was coming from the back wall of the left ventricle. I then found a patient with pericardial effusion and, as predicted, there was now an echo-free space between a moving echo and a nonmoving echo instead of the usual singular moving signal. We proceeded to go to the animal laboratory to confirm this observation. We succeeded, and therein lies the origin of my career in echocardiography.

SKEPTICISM OF ECHOCARDIOGRAPHY

Our work with pericardial effusion was published in March 1965.[25] As with all new technologies, it was difficult to gain acceptance for this test. There are always problems faced by investigators working in a new field. One unique problem was that technology in general did not have a very good track record in the early 1960s. Cardiac ultrasound came on the cardiology scene about the same time that ballistocardiography was on its way out. Apparently, there was great initial enthusiasm for ballistocardiography as the next great cardiological test. Unfortunately, these expectations were never met. As a result, there was skepticism about any new idea, including cardiac ultrasound. I heard of cardiologists who dabbled with ultrasound in those days. They did not have much initial success and abandoned the technology. These experiences contributed to the widespread skepticism and reluctance to accept this examination.

To make matters worse, the few people who were working in the field were not using equipment that was similar. I visited Joyner’s laboratory and found that his instrument produced different recordings than the one we were using. Our echoes were relatively thin, and his were broad. A consequence of these differences was that Joyner could not confirm our technique for detecting pericardial effusion. Although we wrote extensively about the ultrasonic diagnosis of pericardial effusion and this finding was eventually confirmed by several investigators, as late as 1971 there was still considerable skepticism as to whether ultrasound was a useful technique for the detection of pericardial effusion.[26]

With these problems, it is not surprising that it was difficult to get papers published. There were very few qualified reviewers active in cardiac ultrasound, and those few frequently disagreed because of differences in instrumentation. A classic example of this problem is the development of the M-mode technique for measuring left ventricular dimensions. This application is still commonly used today and was probably the development that had the greatest impact in stimulating interest in cardiac ultrasound. This work was done in 1968 and was a collaborative effort between our group at Indiana and Dodge, who was then at the University of Alabama. He had the laboratory with the most expertise in obtaining angiographic ventricular volumes. We brought our ultrasound instruments to Alabama and proceeded to do a collaborative study. We wrote a manuscript describing our findings and were extremely disappointed when the paper was rejected by every major cardiology journal. This experience was very sobering to me. It convinced me more than ever that education and training were critical if this field was to survive.

I proceeded to train Pombo and Troy, who were fellows at the University of Alabama, in our ultrasonic techniques. Popp, who was a cardiology fellow at Indiana at that time, moved to Stanford and introduced the technique there. Popp, Pombo, and Troy then independently repeated the study that we did together at the University of Alabama. They obtained the same results. However, now the situation was different. When they submitted their articles for publication, it was I who reviewed the manuscripts and I accepted them.[27] [28] As a sidelight, I told this story to a friend of mine some years later. I informed him that the original article describing this technique had never been published. He saw to it that it was published in the *Archives of Internal Medicine* 4 years after the work was actually done and after the technique had already achieved popularity.[29]

The first academic course dedicated solely to cardiac ultrasound was taught in Indianapolis in January 1968. Among the faculty were Edler and Joyner. One of the people attending the course was Gramiak, who eventually became one of the leaders in the field. Our laboratory had an open invitation for all who were interested in echocardiography. Many of today's leaders in echocardiography took advantage of this offer. The first book on echocardiography was published in 1972.[30]

CARDIAC SONOGRAPHERS

After a few years of working with cardiac ultrasound, I was convinced that there were many potential applications for this diagnostic tool and that the examination would become very popular. This possibility was "good news/bad news." It was obviously gratifying to know that we were improving the ability to diagnose heart problems. The downside was the demand on the physician's time for doing the examinations. It was conceivable that I could be spending the majority of my working day performing echocardiograms. I felt that it would be possible for a nonphysician to do the echocardiographic examination. The test could be standardized sufficiently so that a nonphysician could create the ultrasonic images, and the physician would do the interpretation. This program was successful, and the field of cardiac sonography using nonphysicians was begun.

The use of sonographers is not universally accepted. The United States is probably the only country where the vast majority of echocardiograms, especially in the adult population, is performed by nonphysicians. One problem with the use of nonphysicians is the occasional case in which enhanced medical knowledge could improve the diagnostic value of the examination. This possibility still requires that the physician have the opportunity to check and correct any echocardiogram. This necessity is especially true in pediatric cardiology, in which complex congenital heart disease is a common occurrence. On the other hand, a well-trained, busy, cardiac sonographer will usually produce higher quality echocardiograms than will the average physician who only records occasional echocardiograms. Many sonographers become extremely skilled and are almost artists as they create their ultrasonic pictures. In today's climate with its desire for cost-effective healthcare delivery, we are very fortunate that cardiac sonographers are available, for they significantly improve the efficiency of this diagnostic procedure.

ORIGIN OF 'ECHOCARDIOGRAPHY'

There are numerous interesting stories behind the evolution of echocardiography. Even the word "echocardiography" has a unique history. As I already indicated, Edler called the technique ultrasound cardiography. His abbreviation for this examination was UCG. In the early days of diagnostic ultrasound, the only examination that had any general popularity was detecting an echo from the midline of the brain to see if it was deviated by an intracranial space–occupying mass. This examination was known as echoencephalography. If the ultrasonic examination of the brain was echoencephalography, then the examination of the heart should be echocardiography. The initial concern was that the natural abbreviation for echocardiography would be ECG. Obviously, this abbreviation was already being used for electrocardiography. We could not use the abbreviation "echo" because it did not differentiate between echocardiography and echoencephalography. The reason echocardiography was finally accepted as the name for this procedure was that echoencephalography disappeared. Now, the abbreviation (echo) is only used for echocardiography. None of the other diagnostic ultrasonic procedures uses the word or term echo.

DEVELOPMENT OF VARIOUS ECHOCARDIOGRAPHIC TECHNOLOGIES

Obviously, there have been many important developments in the field of cardiac ultrasound. They are far too numerous to mention in detail. Suffice it to say that echocardiography is truly an international discipline. Although I indicated that the

Europeans seemed to have lost interest in this area in the early 1960s, it wasn't long thereafter that their interest was rekindled and they returned to the field with vigor. Needless to say, many of the most notable investigators in the field today are European. In fact, transesophageal echocardiography, one of the more important aspects of echocardiography, was primarily developed to its current state by European investigators. Although the first person to describe a transesophageal echogram was an American[31] and Japanese investigators also worked in this area,[32] the technique did not become popular until the Europeans demonstrated how clinically useful this ultrasonic approach could be.[33] A similar story can be told concerning the Japanese and Doppler. One of their most unique contributions to this area was the development of color flow Doppler. Again, the first investigators to write about color flow Doppler were a group of engineers from the University of Washington in Seattle.[34] As with transesophageal echocardiography, the color flow Doppler technique never developed in this country. However, Japanese investigators took this technology and vividly demonstrated to the world how important this examination could be.[35]

The Doppler story is lengthy and truly international. As I mentioned earlier, the Japanese began working with Doppler ultrasound in the mid 1950s. There were several early American investigators who also worked with Doppler techniques. One of these was Rushmer,[36] who was in Seattle and was one of the renowned leaders in cardiac physiology. He worked with an engineer named Baker, who developed the first pulsed Doppler recording device.[37] Reid moved to Seattle and joined the Doppler effort. Strandness made progress with peripheral uses of Doppler.[38] Cardiac Doppler, however, did not attain popularity in the United States. French workers such as Peronneau[39] [40] and later Kalmanson[41] wrote fairly extensively on the use of Doppler ultrasound for cardiovascular needs. The breakthrough in Doppler came when Holen[42] and then Hatle[43] demonstrated that hemodynamic data could be accurately determined with Doppler ultrasound. The report that the pressure gradient of aortic stenosis could be determined with a Doppler recording was probably the most important development that stimulated interest in Doppler echocardiography.[43]

Many other developments in the field had interesting beginnings. For example, the field of contrast echocardiography began at the University of Rochester with Gramiak and Shah. They were performing an ultrasound examination on a patient undergoing cardiac catheterization. A cardiac output determination using indocyanine green dye was being performed. Much to their surprise, this injection produced a huge cloud of echoes within the heart.[44] It happened that Joyner had actually noticed a similar finding with the injection of saline some time earlier, but he never reported that finding. In any case, Gramiak and Shah proceeded to inform the world of the utility of intracardiac injections of indocyanine green dye. I heard their presentation at a meeting and used this approach to verify the identity of left ventricular endocardial echoes.[45] Contrast echocardiography has become an important diagnostic tool. The group from the Mayo Clinic probably best publicized its virtue in the detection of right-to-left shunts.[46] We now have commercial contrast agents that can traverse the pulmonary capillaries and can be seen on the left side of the heart.[47] Interest in this field, which began with an accidental observation, is active and growing.

Many of the early two-dimensional echocardiographic instruments have a fascinating history. The Japanese had a variety of ultrasonic devices for two-dimensional recordings. There were elaborate water baths and scanning techniques.[48] Gramiak, at the University of Rochester, did reconstructive two-dimensional recordings from M-mode tracings.[49] There is some similarity between this approach and what we are doing now in trying to create three-dimensional echocardiograms from two-dimensional recordings. The major difference is that our technology for gating is infinitely better, and present-day computer power did not exist in the early days of two-dimensional echocardiography. The two-dimensional recordings that Gramiak obtained were literally with “cut-and-paste” technology. The first real-time, two-dimensional scanner that gained any popularity was developed by Bom[50] at Rotterdam (Fig 2). This was a linear scanner, and it produced images that were like seeing the heart through a venetian blind.[51] This development was a breakthrough for two reasons. First, it demonstrated rather dramatically the potential of real-time, two-dimensional cardiac imaging. Second, it turned out to be one of the major ultrasonic scanning devices for noncardiac uses. It is somewhat ironic that the linear scanner, which is one of the most popular diagnostic ultrasound devices in general ultrasound, is almost never used for the organ for which it was designed, the heart. Mechanical two-dimensional scanners also have an interesting history. Griffith and Henry[52] at the National Institutes of Health came up with a mechanical device that rocked the transducer back and forth in a somewhat awkward fashion. It was handheld, but the ability to manipulate the transducer was very limited. Eggleton, who originally worked with a major ultrasound group led by Fry at the University of Illinois, moved to Indiana and developed our first two-dimensional scanner.[53] The first prototype that we used was actually a modified Sunbeam electric toothbrush (Fig 3). Eggleton’s approach eventually became the first commercially successful mechanical scanner and was the standard for two-dimensional echocardiography for several years.

CLINICAL IMPACT OF ECHOCARDIOGRAPHY

Echocardiography has come a long way over the past 40-plus years. It is probably the second most popular cardiac test, second only to the resting ECG. There is a variety of ultrasonic examinations now at the disposal of the clinician. The backbone of the current examination is real-time, two-dimensional echocardiography. The M-mode technique is now relegated to a supplemental examination. Although the older technique is still being used to make routine measurements, these measurements are better obtained directly from two-dimensional studies. The real advantage of M-mode echocardiography is its enhanced temporal resolution.

Various forms of Doppler recordings are now routine in all laboratories. There is pulsed-wave and continuous-wave spectral Doppler, color flow Doppler, and new Doppler techniques that are still investigational. Contrast echocardiography consists of injecting tiny bubbles into the vascular system. These tiny bubbles produce clouds of echoes that can be seen on an echogram. Although the usual echocardiographic examination is transthoracic and is truly noninvasive, one can also place transducers at the end of an endoscope and do transesophageal or transgastric examinations of the heart. Ultrasonic technology enables the placement of transducers at the end of a tiny catheter, thus permitting intravascular and intracoronary examinations.

With this instrumentation versatility, it is not surprising that the amount of clinical information provided by a cardiac ultrasound examination has grown over the years. The various examinations provide a highly detailed, real-time examination of cardiac anatomy and function. The Doppler recordings provide valuable and at times unique hemodynamic information. It has been said that cardiologists used to learn hemodynamics in the catheterization laboratory. Now they learn hemodynamics in the echocardiography laboratory. Cardiology is by definition the study of the heart. Echocardiography permits the clinician to visualize and study the heart literally at the bedside. In many ways, the echocardiograph is the true stethoscope. Stethoscope means "seeing through the chest." The instrument we commonly call a stethoscope should really be called a "stethophone." We hear the sounds generated by the cardiovascular system and create a mental image as to what is going on within the chest. Echocardiography permits us to actually see what is occurring beneath the skin surface.

This ultrasonic tool has had an immense impact on our diagnostic ability and our understanding of a variety of disease states. This examination is the procedure of choice for detecting problems such as pericardial effusion, intracardiac masses, valvular and congenital heart disease, and primary myocardial disease and is probably the most practical tool for judging regional left ventricular dysfunction secondary to coronary artery disease. The impact that this test can have on our understanding of disease is probably best exemplified by hypertrophic cardiomyopathy. The ability to measure the thickness of the left ventricular walls and ventricular septum and to record the movement of valves and blood has greatly enhanced our understanding of this fascinating and troublesome problem.

CURRENT RESEARCH AND FUTURE APPLICATIONS OF CARDIAC ULTRASOUND

The versatility and potential of ultrasonic imaging is almost unlimited. The wide variety of transducers, frequencies, and applications that are potentially available means that the ultimate echocardiographic instrument and examination is not in the foreseeable future. All of the current techniques have room for improvement, and investigators and manufacturers are working toward this end. The quality of ultrasonic images is constantly improving. We clinicians are learning how to use the current instruments in more efficient ways. We are improving the techniques of recently developed examinations, such as stress echocardiography, esophageal echocardiography, and intravascular ultrasound. The entire field of contrast echocardiography is accelerating with the introduction of commercial contrast agents that traverse the capillaries. The development of three-dimensional echocardiography is increasing rapidly as we learn how to appreciate the clinical value of acquiring and displaying three-dimensional data.

ROLE OF ECHOCARDIOGRAPHY IN THE NEW ERA OF MEDICAL COST CONTAINMENT

The rapid growth of echocardiography is a classic “good news/bad news” scenario. The bad news is that the examination has become quite sophisticated, and physicians and sonographers must struggle to keep up to date to provide state-of-the-art examinations. There is a learning curve for every new echocardiographic application. Physicians must put in sufficient time and effort to become expert in these new techniques. Like every other aspect of the practice of medicine, echocardiography must be taken seriously. Because the examination apparently does not produce any physical harm and is essentially painless, there is a tendency to let inadequately trained people perform and interpret echocardiograms. In an economic environment in which it is to the financial advantage of physicians and institutions to do as many tests as possible, the prospect of abuse of this apparently innocuous examination is huge. It is no wonder that agencies that are paying the medical bills, such as Medicare, are looking with great concern at the increase in the use of echocardiographic examinations. Not only is there a problem with unnecessary examinations being performed, but inadequate echocardiograms done in mediocre laboratories provide nonspecific or questionable diagnoses that frequently lead to additional tests, which only add more costs to patient care. In the usual fee-for-service environment, this approach may increase income for the physicians, laboratories, and institutions involved. However, in the upcoming era of managed care and/or capitation, such a situation is a financial disaster.

The bottom line is that echocardiography, like every other aspect of medicine, must be done in the best possible way and for legitimate reasons. Mediocre, inadequate, excessive echocardiography will not be tolerated in the new era of cost containment. On the other hand, a well-done, appropriate echocardiogram is an absolute winner in this new economic reality. Because of its relatively lower cost and the potential to provide definitive information, high-quality echocardiography should be a major asset in the cost-containment era. Definitive echocardiographic studies should obviate the need for more expensive, more hazardous examinations in a large percentage of patients and should have a tremendous positive impact on cost-effective patient care.

DIGITAL ECHOCARDIOGRAPHY

One development that may potentially assist in maintaining quality control and improving the efficiency of echocardiography is the advent of digital recording of echocardiograms or digital echocardiography. At the present time, videotape is the dominant medium used for all echocardiography. There are many advantages to videotape. It is inexpensive and can record large volumes of data in real time. The major problem with videotape is that it is difficult for clinicians to view echocardiograms in any convenient manner. As a result, relatively few echocardiograms are seen by any physician other than the one who officially interprets the echocardiogram. Thus, no one is looking over the echocardiographer's shoulder to make certain that the interpretations make sense and the recordings are truly interpretable. An echocardiogram is not that difficult to appreciate. All cardiologists and most physicians who care for cardiology patients should be comfortable in looking at echograms on their own patients. Given the opportunity, they will frequently find something on the recording that might be missed by the official echocardiographer because the clinician knows more about the patient. Having an echocardiographic expert and a clinical expert examine the same recording only provides added value to the test. This is the situation with most other cardiological tests, such as the ECG, chest roentgenogram, or angiogram. Unfortunately, the routine use of videotape interferes with the clinician's ability to view the ultrasonic examination. The tape is frequently unavailable. It may be in the echograph, being used to record a different patient. The tape has to be cued to the proper patient on this 2-hour recording. Then the clinician has to be willing to take 10 to 20 minutes to view the tape in real time. Studying a crucial segment requires repetitive rewinding of the tape.

Digital recordings can be placed on a computer network and made available at numerous stations, including clinicians' offices. Examinations are retrieved in less than 30 seconds and are available 24 hours a day, 7 days a week. The repetitive cine loops permit detailed analysis at one's own speed. Such a display can easily be discussed at length by the echocardiographer and the clinician. In addition, multiple or serial studies on the same patient are easily displayed side by side, something that is impossible with videotape.

SUMMARY

The evolution of echocardiography has been interesting and dramatic. The technology has grown and has become an integral part of the practice of cardiology. As with all technology, there are advantages and disadvantages. The principal disadvantage is the fact that education and training are imperative to provide high-quality examinations and proper interpretations. In addition, many of the diagnoses are still qualitative and subjective.

The principal advantage is the amazing versatility of this technology. The wealth of information that can be provided both noninvasively with a transthoracic examination and invasively with either transesophageal or intravascular ultrasound is tremendous. The anatomic and physiological data provided frequently give definitive diagnoses. If performed properly and for the right reason, this test should be very cost effective and should be a major asset in the coming era of medical cost containment. There are many technological advances that should enhance this information. With technology such as digital recordings, it is hoped that the clinicians will have better access to these data and will be more comfortable in interacting with this important diagnostic tool.

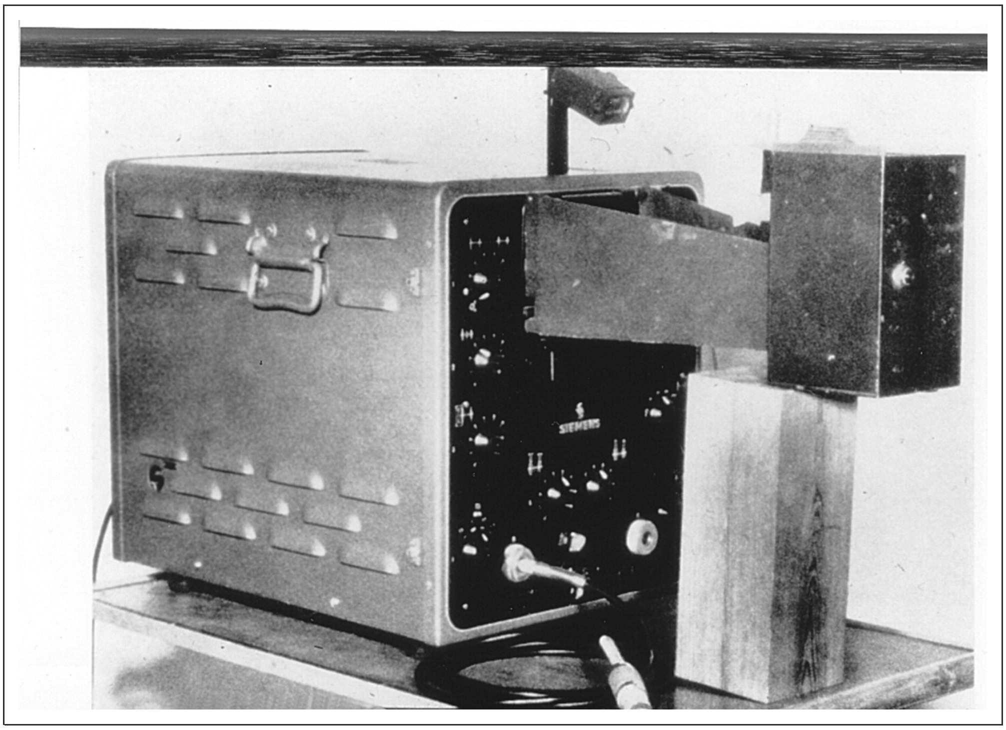

Figure 1. Early echocardiographic equipment used by Edler and Hertz to record M-mode echograms (from Edler et al[17]).

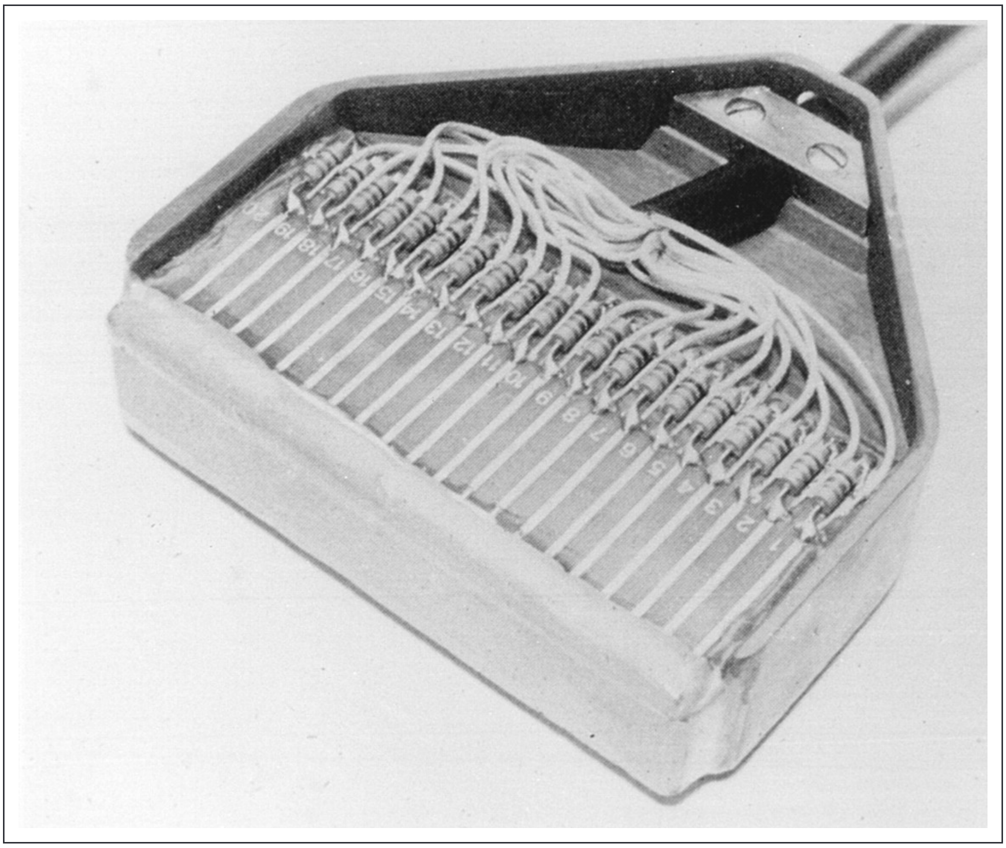

Figure 2. Photograph of a multielement transducer that provides an electronic linear scan and represents the first real-time, two-dimensional, echographic system (from Bom et al[52]).

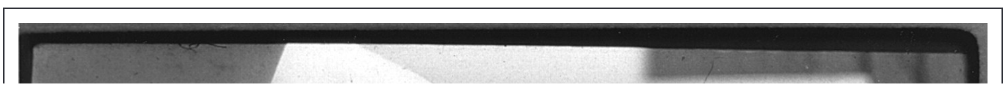

Figure 3. Photograph of an early real-time sector scanner that originated as a modified electric toothbrush.

ARTICLE INFORMATION

Correspondence

Correspondence to Harvey Feigenbaum, MD, Department of Medicine, Cardiac Laboratory, University Hospital and Outpatient Center 5420, 550 N University Blvd, Indianapolis, IN 46202-5250.

Affiliations

From the Department of Medicine, Cardiac Laboratory, University Hospital and Outpatient Center 5420, Indianapolis, Ind. .

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Key Words: echocardiography ■ tests ■ ultrasonics