Perspective

Early History of Diagnostic Ultrasound: The Role of American Radiologists

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First Step into the Unknown

In the late 1940s, after World War II, a few scattered enthusiasts recognized the potential of ultrasonic energy to provide information that could be useful in medical diagnosis. The efforts of these innovators resulted in new concepts and in unique early images that motivated both the manufacturers of instruments and the clinical pioneers to begin to establish meaningful clinical applications for this new phenomenon. The early successes of these individuals created a momentum that encouraged additional users and provided a firm foothold and broadened horizons for this emerging technology. This article examines the highlights of this era as it unfolds up to the late 1960s with emphasis on the contributions of American radiologists.

The earliest pioneers in the United States included three physicians, John Wild, a surgeon, George Ludwig, an internist, and Douglas Howry, a radiologist [1–6]. Of this group, Douglas Howry had the greatest influence on the other pioneers in radiology. In the late 1940s he left a formal residency program at Denver Veterans Administration Hospital to devote more time to ultrasound research. Working in his basement with engineers William Roderick Bliss and George Posakony, Howry pursued his goal of using ultrasound to produce accurate anatomic pictures of soft-tissue structures.

In 1949 Howry and coworkers used surplus radio and Air Force radar parts to build a pulse-echo ultrasonic scanner capable of making two-dimensional images. In 1950, using a 35-mm camera, Howry recorded the first cross-sectional images with ultrasound. However, since only a simple scanning motion was used, without compound sector scanning, the completeness of the anatomic image was not as great because interfaces not perpendicular to the beam could not be recorded. Subsequent instruments were able to correct this initial limitation.

Developing a Clinically Usable Scanner

In 1951 Joseph Holmes, a nephrologist at Denver Veterans Administration Hospital, where Howry was a resident, became associated with Howry and obtained the institutional support needed for the project to proceed. As a result, space was obtained along with a grant. In 1951 Howry and his engineers Bliss and Posakony developed a two-dimensional compound ultrasound scanner. They incorporated an immersion tank by using a cattle-watering container with an ultrasonic transducer mounted on a wooden rail [7]. The transducer, immersed in the tank with the object under study, moved horizontally along the rail [7] (Fig. 1). This method allowed the use of a large transducer (better sensitivity) that could be held away from the patient. The greater distance between the transducer and the patient allowed for better focusing of the ultrasound beam. As a result, the images

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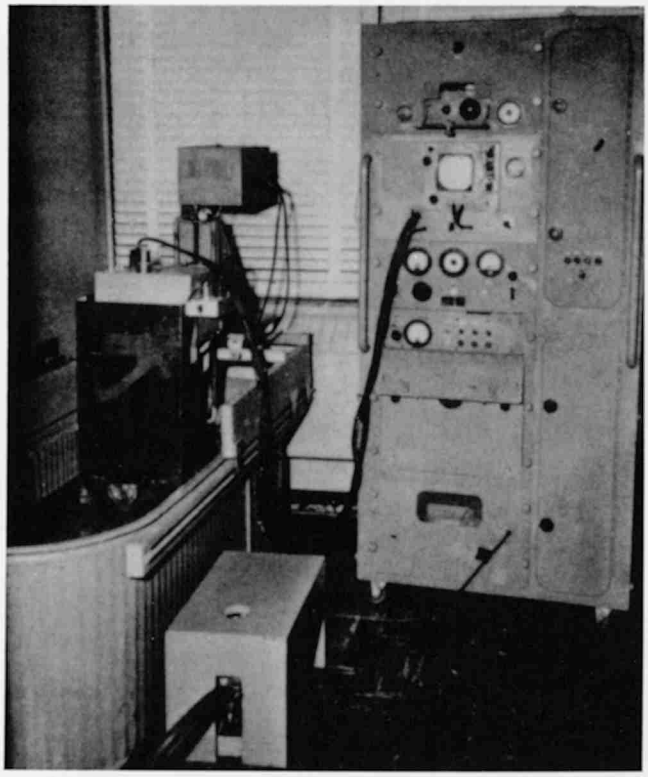

Fig. 1.—Colorado group's earliest successful immersion tank system: the cattle-tank scanner. Transducer, which cannot be seen on this image owing to its submersion in the water bath, was mounted on a wooden rail that ran along outside of tank, which was a watering tank for livestock readily available in the Denver area. Note that, as mounted, the transducer could not completely circle the patient being imaged. (Reprinted with permission from *Medical Diagnostic Ultrasound: A Retrospective on Its 40th Anniversary.*)

obtained with the water-bath method were better than those acquired with the early contact scanners. The first paper on this new development was published in 1952 [5].

A later version, introduced in 1954, included a transducer mounted on a rotating ring gear from a B-29 gun turret, which in turn was mounted around the rim of a large metal cup that served as the immersion tank [7]. This permitted complete horizontal circling of the periphery of the tank while a second motor produced a sectoring motion as the transducer was moved around the tank, producing a compound scanning image of the immersed subject [7] (Fig. 2). Because ill patients could not reasonably be immersed for the long periods that were required for scanning [7], this led to the development, in the late 1950s, of a scanner in which the transducer carriage rotated on a semicircular water-filled pan that was strapped to the patient's body in order to eliminate the need for total immersion [7, 8] (Fig. 3).

Clinical Pioneers

Howry and coworkers recognized the inherent problems with these water-bath coupling systems. In the early 1960s, with collaboration from engineers William Wright and

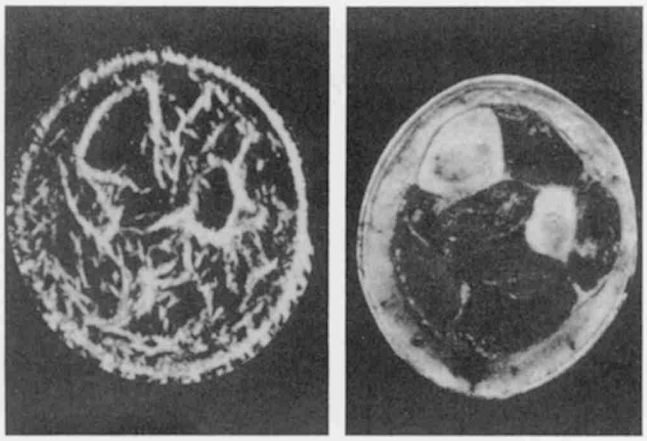

Fig. 2.—Ultrasonic image of human leg produced by compound scanning with the cattle-tank scanner. Leg was placed inside tank, transducer moved in a horizontal path around leg, and a motor provided a second back-and-forth motion of the transducer. (Reprinted with permission from *Medical Diagnostic Ultrasound: A Retrospective on Its 40th Anniversary.)*

Fig. 3.—Howry team's "pan scanner," developed about 1957–1958. Patient sat in a modified dental chair and was strapped against plastic window of a semicircular pan filled with a saline solution. Transducer rotated through the solution in a semicircular arc around the patient. A great many clinical scans were performed with this scanner, which was more appropriate for use on patients than earlier total immersion scanners were. (Reprinted with permission from *Medical Diagnostic Ultrasound: A Retrospective on Its 40th Anniversary.)*

Edward Meyer, the group developed a direct contact scanner. The transducer, mounted within a scanning head, could be positioned by the operator [7].

In 1961, engineers Wright and Meyer left this project to form Physionics Engineering, Inc., and, by 1962, they had produced the prototype of the first hand-held scanner articulated with an arm commercially available in the United States. Physionics marketed this scanner in 1964 as a three-jointed scanning arm incorporating positioning potentiometers at each joint [7].

Howry left Denver in 1962 to join the department of radiology at Massachusetts General Hospital, where he worked until his death in 1969 [9]. Joseph Holmes continued to direct the ultrasound research at the University of Colorado Medical Center until his death in 1982, and influenced a number of radiologists during the 1960s and early 1970s [7]. From this group, in 1966, a medical student, Michael Johnson, worked with Holmes on several projects, including the use of ultrasound in the long-term evaluation of polycystic kidneys and various aspects of echocardiography [10]. Johnson later became a radiologist, then director of ultrasound at the University of Colorado, and is now chairman of the radiology department there.

Looking into the Brain

Another physician influenced by the Howry group was Donald King, a young radiologist at Columbia Presbyterian Medical Center. He was later to combine his efforts with those of Juan Taveras and Ray Brinker in the purchase of ultrasound equipment for that institution. In the spring of 1962, he paid a visit to the University of Colorado. His interest in ultrasound had been stimulated by reading an article in a popular magazine that included an illustration that Howry and Holmes had made of the organs in the body. At that time, Juan Taveras, the director of radiology of the Neurologic Institute also at the Columbia-Presbyterian Medical Center, had an interest in echoencephalography and asked Ray Brinker, who had just completed his radiology residency, to "read up" on what was known about ultrasound. As a result, they combined efforts to obtain a commercial metal flaw detector from Branson Instruments in Stanford, CT, which was used for evaluating the midline of the brain [11]. Branson Instruments later supplied the ultrasound equipment sold by Smith Kline Instruments, which eventually bought Branson. Thereafter, another echoencephalographic instrument made by Physionics was purchased by Brinker, King, and Taveras and, subsequently, in 1964 the first contact two-dimensional ultrasound imager was ordered in an attempt to obtain cross-sectional imaging of the brain [12]. In 1965, Brinker followed Taveras to the Mallinckrodt Institute in St. Louis. There, Brinker developed a water-immersion ultrasound scanner that was unsuccessful because of the difficulty of transmitting the ultrasound beam through the skull [13, 14]. He also carried out early research in Doppler ultrasound [15, 16]. Brinker is currently chairman of the department of radiology at the Medical College of Ohio at Toledo. King, as director of ultrasound at Columbia-Presbyterian, has devoted most of his time to echocardiography.

Abdominal Applications

Another group that influenced a number of radiologists was led by J. Stauffer Lehman, former chairman of radiology at Hahnemann Medical School in Philadelphia. He was a pioneer in clinical applications of ultrasound, specifically, in the diagnosis of abdominal and pelvic abnormalities. The program developed as a result of a chance meeting in 1964 between Luther Brady, chairman of radiation therapy at Hahnemann, and Murray Smyth, also a radiologist, who was involved in promoting the clinical uses of ultrasound equipment produced by Smith Kline Industries. He had approached several other medical schools and facilities in Philadelphia but found no interest. At that time, Smith Kline was producing the Ekoline A- and M-mode series for echoencephalography and echocardiography and was considering adding B-mode two-dimensional ultrasound instruments to its product line. At Brady's suggestion, Smith Kline Instruments provided the B-mode equipment and Lehman provided the staff to perform the clinical tests [7] (Fig. 4).

George Evans, a young radiologist who had trained at Hahnemann, was asked to organize the ultrasound laboratory and supervise the clinical testing [7]. It was his job to investigate the diagnostic applications of bi-stable ultrasound water-bath techniques and abdominal scanning. Insights into the personalities of Lehman and Evans are provided by a letter written by George Evans: "My personal aggressive enthusiasm toward ultrasound was tempered by the conservative yet perceptive approach of Dr. Lehman. His painstaking diligence and his profound circumscription infected all who worked with him. His insistence for accuracy and reproducibility of results were ubiquitous. These characteristics were so ingrained in his approach to research that we did not make unfounded conclusions as regards to the diagnostic capabilities of ultrasound."

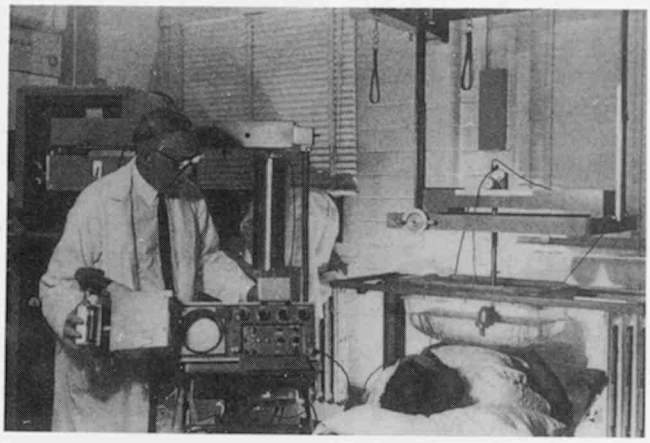

Fig. 4—J. Stauffer Lehman scanning a patient with a compound scanner built by Smith Kline Instruments and General Precision Instruments. Transducer moved in a water bath lowered over patient's abdomen. (Reprinted with permission from *Medical Diagnostic Ultrasound: A Retrospective on Its 40th Anniversary.*)

Broadening Horizons

Marvin Ziskin, currently a professor of radiology at Temple University, became aware of ultrasound as a student in biomedical engineering at Drexel University in 1964, when Murray Smyth presented a seminar. In 1965, Ziskin became a research associate in the diagnostic ultrasound laboratory at Hahnemann under the direction of Lehman, who died in 1974, and Evans, who is currently in private radiologic practice in Detroit. This group did some of the earliest large-scale clinical research with ultrasound imaging [17, 18]. In addition to investigating abdominal applications, they also carried out research in echoencephalography, echocardiography, and Doppler ultrasound [19–21]. Evans' first paper was presented in December 1964 at the Greater Philadelphia Chapter of the Federation for Clinical Research. The ultrasound images from the Hahnemann laboratory were published in *Life* magazine in January and September 1965. This group presented the first exhibit on ultrasound at the annual meeting of the American Roentgen Ray Society in September 1965 and again at the Radiological Society of North America (RSNA) in November 1965.

Lehman, Evans, and Ziskin worked with practically every type of ultrasound instrument manufacturer in the country at that time and it is said that Lehman was instrumental in persuading Picker to become involved in ultrasound. Picker later bought Physionics and became the dominant force in two-dimensional ultrasound imaging in the 1960s and early 1970s. The company helped disseminate the use of ultrasound throughout the radiologic community.

In 1968 Barry Goldberg joined the staff at Hahnemann, where he worked closely with Lehman in expanding the clinical usefulness of ultrasound [22]. Goldberg developed an interest in ultrasound during his radiology residency in Philadelphia at the Albert Einstein Medical Center in 1964. J. Gershon-Cohen, former chairman of radiology at the Center and a pioneer in X-ray mammography, had just bought one of Smith Kline Instruments' first Ekoline A-mode ultrasound machines. A few weeks after Goldberg started his residency he asked Dr. Gershon-Cohen about the machine in the hallway. Gershon-Cohen replied, "Well, that's something new, ultrasound, see what you can do with it." Goldberg became enthusiastic about the technique as he and his colleagues taught themselves to use the equipment. Working with several members of the radiology staff, he published articles on a variety of subjects, including echoencephalography, echocardiography, and abdominal and pelvic diseases, as well as producing images of the fetus [23–28]. With John Kirkpatrick, then chairman of radiology at St. Christopher's Hospital in Philadelphia, Goldberg was one of the first to investigate the use of ultrasound in pediatric radiology. Goldberg and H. H. Holm, a urologist from Denmark, were the first to develop ultrasound-guided aspiration biopsy techniques. In 1965, Goldberg delivered one of the first ultrasound papers given by a radiologist at a meeting of the RSNA. He pioneered the development of formal educational programs for physicians and technologists. He is now director of ultrasound at Thomas Jefferson University Hospital.

George Leopold began his radiology residency in 1965 at Presbyterian Hospital in Pittsburgh. Elliott Lasser, then chairman of radiology, obtained a Smith Kline Instruments' ultrasound A-mode unit after the 1966 annual meeting of the RSNA and assigned several residents to evaluate its capabilities. Leopold was the only resident to maintain an interest, working first with echoencephalography and then echocardiography. His introduction to B-mode imaging was a Picker machine lent by the company to the hospital for evaluation. Shortly after a visit to Lehman's laboratory, Leopold followed Lasser to the University of California at San Diego and dedicated himself to the clinical applications of diagnostic ultrasound [7]. When Leopold arrived in San Diego in 1968, he called a local Picker salesman and told him that he wanted to order an ultrasound machine. The salesman said, "Fine, Doctor, what is it? If we have such an instrument, we'd be happy to sell it to you." This was to be the first such machine on the West Coast. Leopold's early research was on abdominal ultrasound [29, 30]. He is now chairman of the department of radiology at the University of California, San Diego. Like Goldberg, Leopold stressed education, providing both formal and informal training programs. They, along with other early clinical pioneers, educated a whole generation of radiologists and technologists in the usefulness of diagnostic ultrasound.

Ultrasound Becomes Popular

Another center of clinical research and training was developed under Atis Freimanis, a radiologist at Ohio State University, who in the mid-1960s also visited Lehman's laboratory to observe clinical work with the Smith Kline Instruments' water-bath prototype [7]. Originally interested in its application in studying the nervous system, Freimanis became impressed with the general diagnostic capabilities of ultrasound [7]. At Ohio State he worked with Michael Asher, at that time a medical student interested in developing some collaborative research projects [7]. He and Freimanis conducted early research on the imaging of enlarged retroperitoneal lymph nodes, and they designed their own scanning system and techniques [31]. Shortly thereafter, another radiologist, Roy Filly, then a medical student, joined them in some of their early ultrasound research on pancreatic abnormalities. Asher is now in private practice and Filly is now the director of ultrasound at the University of California, San Francisco. This is yet another example of how the early pioneers in clinical ultrasound provided the stimulus for the next generation of radiologists, who, in subsequent decades, took ultrasound to its current high levels of use. Freimanis eventually became chairman of radiology at the Medical College of Ohio at Toledo and then at Ohio State; he now continues in academic practice at Michigan State University.

In the 1960s, a number of radiologists directed their initial efforts toward research with echoencephalography. Many of these individuals did not further pursue ultrasound, probably because of the difficulty in obtaining adequate images of the brain due to the poor penetration of the ultrasound beam as it passed through the adult skull. It was not until the 1970s, when researchers began to use the fontanelle in pediatric patients for placement of the transducer, that adequate information from two-dimensional imaging became available. In

1967, for instance, at Downstate Medical Center of the State University of New York, Lewis Grossman, a neuroradiologist and amateur physicist, directed an active laboratory at the Neurologic Institute with the assistance of Georgina Wodrowska, who was one of the earliest ultrasound technologists. Unfortunately, Grossman died in 1969. Michael Tenner, also a neuroradiologist and now chairman of radiology at New York Medical College, was asked to head the service. He helped to extend the use of echoencephalography beyond simple midline detection by identifying various components of intracranial anatomy. In 1963, Marc Lapayowker, a radiologist at Temple University in Philadelphia, and John Kirkpatrick used an Ekoline instrument to perform echoencephalography examinations, including examinations of children [32, 33]. With Renata Soulen, another radiologist, they attempted to duplicate the early work of Harvey Feigenbaum, a cardiologist, in the ultrasound evaluation of pericardial effusion [34, 35]. Lapayowker was the first chairman of the American College of Radiology Commission on Ultrasound and is currently chairman of radiology at Abington Hospital near Philadelphia.

Fred Winsberg, a radiologist and currently director of ultrasound at Mount Sinai Hospital, was first introduced to ultrasound in 1967 while working at Lincoln Hospital in New York. As he stated, "Although I had been promised a renovated X-ray department, construction was delayed by the usual governmental red tape and the only items I was able to purchase were those not requiring construction. Thus, I acquired a Hoffrel ultrasound machine designed for echoencephalography with M-mode capability." This machine was designed by Russ Uphoff, an engineer who had left Branson to form his own company. Winsberg soon became disenchanted with cerebral midlines, but fascinated with echocardiography. He presented his first work in differentiating the left from the right ventricle in 1968 at the annual meeting of the American Institute of Ultrasound in Medicine. In the spring of 1970, he traveled to Germany to see the first and only real-time ultrasound instrument at that time, a Vidoson sold by Siemens. He was the first to use this machine in North America at McGill University in Montreal, Canada, where he performed ultrasound on a full-time basis. Winsberg worked with another radiologist at McGill, the late Catherine Cole-Beuglet. Using the Vidoson, which featured a rotating transducer placed at the focal point of a parabolic mirror producing real-time images [36], they were able to visualize the aorta and show pulsations, establishing the value of real-time ultrasound.

Raymond Gramiak, a radiologist at the University of Rochester, began his involvement with ultrasound in 1966 when the radiology department unexpectedly discovered a budget surplus. Purchase of an ultrasound machine was suggested by Elliott Lipchik, cardiovascular radiologist, because it appeared new and exciting. A Physionics unit was selected because it featured a storage oscilloscope for monitoring image build-up during M-mode sweeping or B-mode scanning. Gramiak showed the greatest interest in mastering use of the new machine and soon obtained meaningful M-mode images of the mitral valve, virtually the only regularly recognized cardiac structure at that time. By varying beam directions away from the mitral landmark and into the area expected to contain the aortic valve, an echo-pattern complex that seemed to represent the aortic valve could be detected. By good fortune and, at about the same point in his development as an echocardiographer, Gramiak examined a patient in the cardiac catheterization laboratory during cardiac output studies with indocyanine green. Each intracardiac injection of the agent resulted in an intense contrast effect, which he instantly recognized as an excellent method to correlate cardiac anatomy with the nonanatomic display of M-mode sonography. It became apparent that the aortic valve echo complex could be anatomically validated by injection of contrast material [37]. This work was soon followed by a more comprehensive study in which the anatomy of the cardiac chamber, patterns of the mitral, tricuspid, and aortic valves, and a variety of clinical conditions were shown by using ultrasound and injections of contrast material [38].

A number of others, both radiologists and nonradiologists, have made important contributions. Nonradiologists include Ross Brown, who was director of ultrasound in the department of radiology at the University of Oklahoma in the 1960s and early 1970s, and Kenneth Taylor from England, who has been the director of the division of ultrasound in the department of radiology at Yale since the early 1970s. In addition, in the early 1970s, Roger Sanders, another Englishman and a radiologist, former director of ultrasound at Johns Hopkins University, made important contributions, and Donn Brascho, now medical director at Baptist Cancer Hospital, was the first radiologist to use ultrasound as an aid in planning radiation treatment.

Epilogue

The decade of the 1960s was a dynamic, challenging, and somewhat difficult period for radiologists involved in diagnostic ultrasound. At the onset of this period, ultrasound evolved from a medical curiosity to a recognized clinical procedure, capable of providing unique diagnostic information. However, instrumentation was crude and huge voids in interpreting images confronted the dedicated practitioner. In radiology, the established hierarchy was skeptical, particularly because tissue representation in the ultrasound image was different from that on conventional radiologic images, so physicians with considerable skill and experience in interpreting X-ray images could not readily interpret sonograms. The relatively poor resolution and the difficulty in imaging tissue such as lung, bowel, and bone also proved barriers to acceptance even though different tissue properties were evident on sonograms as compared with radiographs. As a result, radiologists striving to make their mark in ultrasound often received less than optimal departmental support. Despite this atmosphere of resistance and lack of instrumentation, radiologists persevered and made progress in the development of diagnostic ultrasound.

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