Sam N. Hassani

ultrasound in gynecology and obstetrics

(in collaboration with R. L. Bard)

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foreword

by Dr. Donald L. King

The past decade has seen the ascent of ultrasonography to a preeminent position as a diagnostic imaging modality for obstetrics and gynecology. It can be stated without qualification that modern obstetrics and gynecology cannot be practiced without the use of diagnostic ultrasound, and in particular, the use of ultrasonography. Ultrasonography quickly and safely provides detailed, high-resolution images of the pelvic organs and gravid uterus. The quality and quantity of diagnostic information obtained by ultrasonography far exceeds anything previously available and has had a revolutionary impact on the management of patients. High-resolution static images permit the intrauterine diagnosis of fetal growth retardation and fetal abnormalities. In addition to traditional images, newer dynamic imaging techniques allow observation of fetal motion, cardiac pulsation, and respiratory efforts. The use of ultrasonography for guidance has greatly augmented the safety and utility of amniocentesis.

One of the great virtues of diagnostic ultrasound has been its apparent safety. At present energy levels, diagnostic ultrasound appears to be without any injurious effect. Although all the available evidence suggests that it is a very safe modality and that the benefit to risk ratio is very high, the actual safety margin for its use as yet remains unknown. As a consequence, practitioners are urged to limit its use only to those situations in which genuine clinical indications exist and real benefit to the patient is likely to result.

The future will bring with it greater understanding not only of the biologic effects of ultrasound but many new techniques for its application in diagnosis and therapy. One of these, the use of pulse-Doppler ultrasound, will almost certainly be valuable to assess and eventually measure blood flow in the uterine arteries, placenta, and within the fetus itself. The vast potential of diagnostic ultrasound as yet has hardly been exploited. The great growth of the past decade will eventually be overshadowed by even greater progress in the future.

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foreword

by Dr. Jan J. Smulewicz

In his recent book, Dr. Hassani did a very thorough exploration and an excellent explanation of the wide variety of examinations in the field of obstetrics and gynecology with the ultrasonography method. I found the book very easy to read, the interpretation very clear, and the large volume of material excellently chosen. I am sure that the book will be of great interest to practitioners, especially obstetricians and gynecologists. This method being noninvasive and eliminating the danger of ionizing radiation, should find its way into every hospital or center where good medical care is provided.

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We are also very grateful to Akram Hassani, Nat Lewis, John H. Grant, Marie Snailer, Judy Sharpe, Lee Weingarten, R.D.M.S., and Sonia Suga for their technical assistance.

The investigative efforts of our many colleagues in the field of ultrasonography have greatly facilitated the evolution of this textbook. The support of the publishers and the collaboration of the Editorial Staff are warmly acknowledged.

preface

Ultrasound imaging has reached a stage of sophistication whereby diagnostic information can be gained without discomfort to the patient and with complete absence of morbidity and mortality. The procedure is quick, safe, noninvasive, and, in many instances, supercedes and obviates more time-consuming procedures requiring catheterization, injection of a contrast material, and radiographic imaging. In obstetric problems, the danger of ionizing radiation to the fetus is eliminated. In debilitated and very ill patients this simple and painless method becomes the procedure of choice.

Unique features of ultrasound equipment allow for pinpoint localization of lesions and direct visual guidance of percutaneous puncture techniques for aspiration and biopsy. The accuracy of ultrasound-guided cystic punctures and the absence of side effects make this modality far superior to percutaneous invasive techniques performed with other imaging systems. Renal cyst puncture and amniocentesis are but two of the procedures in which ultrasonic guidance is the method of choice. Since this modality is noninvasive, it may be performed serially and at any given time.

This sequential observation of pathophysiology in the fetus and the mother provides important data on the progression of acute and chronic diseases and their response to treatment. The unusual accuracy of ultrasound in differentiating cystic from solid masses and its ability to localize the lesion in a three-dimensional representation have rendered other diagnostic procedures unnecessary for the practicing obstetrician and gynecologist. The standard radiologic evaluation for abdominal masses has generally included the plain x-ray film of the abdomen, intravenous urography, barium enema, gastrointestinal series, cholecystography, and radioisotopic procedures. Invasive and time-consuming studies such as lymphangiography and arteriography have also been used, sometimes without adding further diagnostic information. Sonography is safe and relatively inexpensive and should be included in the workup of a mass lesion. Since ultrasound may give a specific diagnosis, its application should follow the plain x-ray film. This simple and rapid study may eliminate the need for a prolonged hospital stay and the discomfort of further examinations. Diagnostic ultrasound has greatly reduced the patient time spent in the x-ray department, giving the obstetrician and gynecologist faster and more reliable diagnostic information, and generally speeding up the patient turnover at the hospital. With the economic emphasis on the cost reduction of medical services and hospitalization expense, the ultrasound department serves a vital function in facilitating diagnostic services.

The purpose of this book is to introduce the physician to the essential principles of ultrasound physics and the practical aspects of scanning procedures. Important concepts are clearly and thoroughly presented. Mathematical formulas and advanced physics principles beyond the scope of the clinician have been omitted. The text is limited to the pelvis and medically related areas in order to concentrate on each area in sufficient depth so as to be valuable to the specialist who must be familiar with the diagnostic capabilities of atraumatic scanners in his field. The methods of examination and diagnostic findings are detailed to be useful to the obstetrician, gynecologist, radiologist, and general surgeon. The comprehensive scope serves as a general reference for both the family practitioner and the student in training.

In the sections on physical and practical applications, precise directions for examination are given and scanning pitfalls with the production of artifacts have been underscored. The evolution of scanning systems has been traced so that the potential features and limitations of each imaging unit are recognized. Representations of each type of scanning device are illustrated and their inherent advantages discussed.

Examination of each area has been arranged so that the reader may review the pertinent regional anatomy before studying the ultrasonic presentation of normal structures. The pathology of each organ is presented as a disease spectrum and the evolution of the disorder is discussed. Correlation between sonographic findings and the histopathologic changes is emphasized. The combination of real-time and gray-scale scanning offers the reader a comprehensive understanding of ultrasonic pathology.

Where controversy exists, the opinions of various authorities are cited and compared with our experience. The diagnostic versatility of the various imaging systems are evaluated for each organ complex and the investigative method of choice is suggested for each disorder.

Considerable attention has been given to clinical and pathologic aspects. The practice of ultrasonic scanning requires a thorough knowledge of the diagnostic problems of obstetrics and gynecology and their related specialties. The text is designed as a bridge between sonographic imaging and general obstetric and gynecologic principles.

introduction

Diagnoses are missed not because of lack of knowledge on the part of the examiner, but rather because of lack of examination.

Sir William Osler

The field of diagnostic ultrasound has expanded in application so rapidly over the past few years that it has become part of the routine diagnostic workup. The history of ultrasonography is vastly different from the evolution of X rays. After the discovery of the X ray in 1885, it was rapidly accepted by the medical community and many radiologic societies soon appeared. The imaging potential of X rays was so exciting that many patients and their physicians received massive exposure to this form of highly penetrating electromagnetic energy. The dreadful sequelae of radiation-induced injuries and malignancies subsequently appeared.

The development of ultrasonography is quite different. In spite of the absence of demonstrable side effects and the

ease and accuracy of the study, its use did not become fashionable until very recently. The nature of the sound beam is that of mechanical energy and its possible long-term biologic effects still remain unclear. However, it is known that the ionizing effects of X rays make even small doses potentially harmful. Sonar mechanical vibrations are such that energy below the level that breaks tissue bonds will not produce any tissue damage. Our experience to date with low intensity ultrasound suggests that no hazardous effects will occur in the short or long term in patients.

The field of ultrasonography has assumed such importance primarily as a result of the harmless nature of the modality. Also, the tireless efforts of a large number of investigators from varied medical fields and allied services have developed sonography into one of the best diagnostic tools. The pioneers in ultrasound, using only A-mode to combat the skepticism of their colleagues, must have been exceptionally dedicated and patient. Scanning the abdomen and mentally integrating thousands of A-mode spikes to give an answer to the clinician in need of a firm diagnosis must have produced great frustration. This problem was alleviated by the introduction of B-mode scanning units. Soon this technique was followed by the time-motion– or M-mode.

My personal experience with ultrasonography began with the late Dr. Lajos von Micsky and his experiments conducted in a water tank. This type of study was mainly intended to produce higher quality pictures in order to improve diagnostic accuracy. The introduction of Doppler ultrasound proved to be an instant success with clinicians in the evaluation of the fetal heart. The idea of scanning the pelvis with a full bladder opened the ultrasonic door to the visualization of the deep pelvic organs and dramatically improved diagnostic accuracy in this region.

The true revolution in ultrasonography began with the development of the scan converter with its sophisticated logarithmic compression amplifiers. This presentation of a scan in various shades of gray related to echo amplitude opened new horizons in the study of tissue signatures. Soon we were imaging the medium-sized arteries and veins in the upper abdomen and, comparing these with our anteroposterior (AP) and cross-table lateral angiograms, we were able to sonographically map the organs in relation to the vascular anatomy.

The fundamentals of ultrasound, like those of any other branch of medicine, require the user to be familiar with the effects and limitations of the method. By this technique we are able to locate different organs and tissues and measure the interfaces between them, and to cut in cross sections through different structures. In contrast to other examinations which yield indirect information, ultrasound enables us to outline the lesion directly and to investigate its relationship with neighboring structures. There is no need for the administration of any radiologic contrast, possibly harmful to the function of the impaired organ. Ultrasound, both as a screening and diagnostic modality, is a noninvasive and atraumatic procedure and is complimentary to angiography in many cases. The unique feature of ultrasound is the ability to recognize and differentiate deep body organs and lesions having similar density on conventional X-ray studies.

The information gained through ultrasound, as in other imaging procedures, is optimized when coupled with the patient's clinical picture. At present, parenchymal lesions of the lung cannot be evaluated by ultrasound since the air-containing lung will not transmit sound waves.

The history of ultrasonography is a long one and the procedure has suffered from many setbacks in its attempt for acceptance by the medical profession. Its inherently harmless nature has accounted for a significant portion of its popularity in modern medical practice. Whether the sophisticated electronic technology that spawned high resolution ultrasound will cause the growing field of ultrasound to supersede other diagnostic modalities, or create nonultrasonic imaging systems that will phase out ultrasonography, remains to be determined.

The pioneers of ultrasonography had much difficulty in applying sonar to diagnosis since they were using first generation scanners based on ultrasonic technology used in industry and military pursuits. In later years newer ultrasonic units designed to meet specific clinical purposes have been constructed. Cooperation of physicists, engineers, and physicians dedicated to ultrasonic imaging has led to development of diagnostic systems of considerable practical v..lue. Since the early days of the applicati... sonar principles in medicine, there have been continual new innovations in this field. The progress of acoustic waves in diagnostic imaging has been aided by the development of special ultrasonic transducers, sophisticated amplifiers, and sensitive electronic displays. The introduction of recently perfected scan converter systems adds a new dimension to the field of ultrasonography.

The word sonar is an acronym of sound navigation and ranging. Historically, ultrasound was developed during World War I. Langevin (1) used the principle of sonar to detect and locate submarines. Sounding of the ocean floor to provide depth measurements was employed in 1918 to aid in shipping and navigation (1). Further improvement in technology created more extensive usage of sonar in industry and military situations. Military sonar used by the navy could measure the depth of a reflecting surface and also track an object in motion. In 1930 ultrasound was used in industry to detect flaws in iron castings. Prior to World War II, Dussik (2) used ultrasound in the field of medicine. His attempt to visualize the ventricular system of the brain was unsuccessful. However, in 1937, he designed an ultrasonic device for application to the brain (3). The first ultrasonic instrument, called the supersonic reflectoscope, was introduced in 1940 (4). This practical instrument, based on the pulse-echo technique, measured distance on the principle of transmission of very short pulses of sonic energy. During World War II the application of radar principles in military imaging further helped to develop the sonar technique. The conjoint use of both imaging systems speeded progress in each field and led to the availability of the first medical sonar units in the late 1940s and early 1950s.

Continuing new developments in ultrasound were spurred on by dedicated researchers. The application of new electronic circuitry and rapid reporting data retrieval systems changed the use of ultrasound from that of a research tool to an essential diagnostic modality. The fields of echoencephalography and then of M-Mode echocardiography were developed. Next, unidimensional and two-dimensional ultrasonic scanning were combined.

As various medical teams cooperated in the development of ultrasonic scanners, smaller and more practical ultrasonographic units became available. Pioneer work in the use of ultrasonography in obstetrics and gynecology was done by Thompson (5) and Gottesfeld (6). W. L. Wright designed a hand-operated ultrasonic unit. Subsequently many compact commercial ultrasonographic units became available. J. J. Wild made great contributions to the field of ultrasonography. In particular, he devoted his work to the differentiation of benign and malignant tumors (7).

When the prototype of the contact ultrasonic scanner became more popular, since the transducer could now be placed on the patient's skin with direct contact, many further advances in equipment design became possible. Water bath scanning of the eye (8) was another technical development, and was soon followed by the application of time-motion displays (9). By using two-dimensional real-time scanning systems respiratory and vascular motion can be detected and pathological conditions evaluated, in addition to detection and evaluation of their three-dimensional images.

At present, use of ultrasonography is spreading into many branches of medicine. It has become an integral part of many subspecialties, such as obstetrics and gynecology and urology, since it is one of the most accurate diagnostic tools in many disorders involving soft tissue pathology.

Modern electronics has given the medical sonographer high-resolution equipment which is relatively simple to use. The application of ultrasonography has been so rapid that it is now the preferred diagnostic test in many clinical problems. In certain disorders, such as placenta previa, it is virtually the only diagnostic tool that is available.

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1 principles of ultrasonography

CHARACTERISTICS OF ULTRASOUND

NATURE OF ULTRASONIC WAVES

Sound is a mechanical vibration of particles in a medium around an equilibrium position. Sonic waves require a medium of a molecular nature in order to propagate. The highest frequency audible to the human ear is 20,000 cycles per second or 20 kiloHertz (KHz). Sound waves above this frequency are described as ultrasound. Unlike electromagnetic waves, sound cannot travel across a vacuum (10).

The wavelength of audible sound in air varies from a few inches to a few feet. Ultrasonic waves are usually produced by a continuous series of contractions and relaxations of substances that have piezoelectric properties. The waves generated are carried as condensations and rarefactions in the transmitting medium. The frequency range used in diagnostic medicine is approximately 1 million cycles per second, with a wavelength of about 1.5 millimeters (mm) in water.

PIEZOELECTRIC PRINCIPLE

The piezoelectric effect is fundamental to the development of ultrasound. ''Piezo'' is derived from the Greek word *piesis,* ie, to press. Piezoelectric actually means ''pressure electric.'' Quartz has piezoelectric qualities, since its size and shape change under the influence of an electric field. When an electric current is passed through quartz, the crystal expands and contracts according to the polarity of the current. Sound waves are generated as a result of these compressions and rarefactions. On the other hand, mechanical energy, in the form of sound waves applied to the crystal, produces an electric current. This is known as the piezoelectric principle (Fig. 1.1a and b). Several other substances are known to have piezoelectric properties, such as barium titanate, lithium sulfate, and lead zirconate (11). The titanates are the more commonly used crystal (10) for sonography.

SOUND WAVES

Sonic waves travel through a medium as alternate condensations and rarefactions. The following practical definitions are commonly used (Fig. 1.1c).

1. Cycle. One cycle is the entire condensation and rarefaction phase.
2. Wavelength. The length of one cycle is a wavelength, or, a complete condensation and rarefaction zone is a wavelength.
3. Frequency. The number of cycles per unit time. The frequency of sound waves is described in terms of hertz (cycles per second).
4. Velocity. Velocity is the speed of sound in the medium through which sound is propagated.

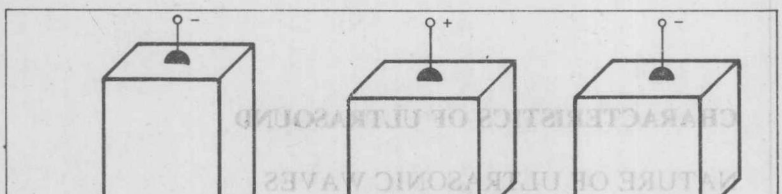

FIGURE 1.1
Piezoelectric effect. (a) Mechanical stress deforming crystal and producing current. (b) Expansion of crystal as current is applied and contraction of crystal as current polarity is reversed. (c) Wave pattern produced by alternate compressions and rarefactions. A, spatial pulse length; B, full cycle; C, wavelength; D, amplitude.