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real time ophthalmic ultrasonography

(in collaboration with R. L. Bard)

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real time ophthalmic ultrasonography

To Our Families

foreword

by Dr. Nathaniel R. Bronson, II

This volume serves a two-fold purpose very nicely. For the ophthalmologist there is a presentation of the techniques and results of ultrasonic examination of the eye and orbit. For the radiologist or general ultrasonographer the essential ocular anatomy and pathology are described with these findings. Unlike conventional x-rays or static general body ultrasonograms, the examination of the eye by real-time ultrasonography must be done by an examiner with extensive personal knowledge of the eye and the orbit, both anatomically and pathologically. The student must realize that the Polaroid photographs can only show an example of what was transiently seen, such as spot films taken during fluroscopy. This is further complicated by the poor reproduction by Polaroid films of the actual gray scale seen during the examination.

Considerable work has been done to prepare this text. The author has done clinical ultrasonography of many eyes and presents the findings of his experience. As in most fields of medical diagnostic work this experience is essential to achieve the best results. The beginner in ophthalmic ultrasonography is encouraged to work with known pathology. Fortunately, pathologic changes in the eye can frequently be seen with a slit lamp or an ophthalmoscope. For example, a known retinal detachment is an ideal case with which to start. The sheet-like echoes leading to the optic nerve can be compared with ophthalmoscopic findings. One has more confidence then when similar sheet-like echoes are seen in an eye with opaque media, such as when a dense cataract or a vitreous hemorrhage is present.

The author describes what is one of the most important factors in real time ophthalmic, and I suspect general body, ultrasonography: three-dimensional thinking. On the screen one sees a two-dimensional image, but by angulation and rotation of the scan head this can and should be built up into a three-dimensional image in the examiner's mind. In the course of teaching this technique we have found this concept of three-dimensional thinking easy for some and difficult for others. For the latter I encourage them to work with test objects, such as a paper clip, in a dish of water constructing the three-dimensional image mentally.

The text describes the need to combine the ultrasonic findings with those of other examinations. While I feel confident in diagnosing a malignant melanoma of certain types and sizes in an eye, I would never suggest enucleation on that basis alone. This was brought out recently when we compared our ultrasonic diagnosis of orbital masses with those of the same patient done on a CAT scanner. In many cases both of us were wrong, but the combination of the two techniques significantly improved the diagnostic accuracy.

Ophthalmic ultrasonography has grown steadily over the years from the pioneering work of Mundt and Hughes, Oksala, Baum, and Purnell, but only in the last few years has its clinical use become widespread. The eye is an ideal organ for ultrasonic examination. The distances are short, and the acoustically clear vitreous is much easier than elsewhere where bone and gas are present. Ultrasonic advances in equipment are usually shown first in ophthalmology as a result of the acoustic environment. For example, gray scale has been in use in the eye for nearly two decades.

Enjoy your ultrasonic work. It is fun and interesting, and much pathology will be seen. For the ophthalmologist, learn the basics of ultrasonography. For the radiologist or ultrasonographer, work closely with your ophthalmologist to learn ophthalmic anatomy and pathology.

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preface

Ophthalmic ultrasonic scanning has reached a stage of sophistication whereby detailed diagnostic information can be gained without discomfort to the patient. The procedure is quick, safe, noninvasive, and in many instances, supersedes and obviates more time-consuming procedures requiring catheterization, injection of contrast material, and serial radiographic imaging.

Real-time scanning is particularly useful in pediatric and geriatric patients. The adaptability of the scan head to any conceivable patient position and the portability of the machine smooth out many logistical problems in patient examination. The ability of the scanner to provide diagnostic findings in the presence of motion salvages many a study on an uncooperative patient. This advantage is not possible with a static B-scan unit. Indeed, the capability of evaluating the motility of a pathologic process is often the key to differentiating lesions that may have similar ultrasonic morphology. The motion of a linear segment of vitreous hemorrhage is far greater than a retinal detachment. This feature readily distinguishes the important disorders. Since this modality is noninvasive, it may be performed serially and at any given time. Multiple studies to optimally evaluate the biologic nature of a lesion are completely without morbid effects to the extremely delicate structures of the eye. The lens, in particular, is highly sensitive to ionizing radiation which results in early cataract formation. This undesirable consequence promotes the use of ultrasound when serial studies are considered.

The purpose of this book is to introduce the physician to the essential principles of ultrasound physics and the practical aspects of ophthalmic 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 eye and medially 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 scanning in his field. The methods of examination and diagnostic findings are sufficiently detailed to be useful to the radiologist and ophthalmic surgeon who are serious practitioners of ophthalmic scanning.

In the sections on physical and practical applications, precise directions for examination are given and scanning pitfalls with the production of artifacts are underscored. The scanning systems are presented so that the potential features and limitations of the imaging unit are recognized.

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 structure is presented as a disease spectrum and the evolution of the disorder is discussed. Correlation between sonographic findings and the histopathologic changes is emphasized.

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 is given to clinical and pathologic aspects. The practice of ultrasonic scanning requires a thorough knowledge of the diagnostic problems of ophthalmology and their related specialties. The text is designed as a bridge between sonographic imaging and general ophthalmic principles.

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

introduction

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 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 unforgettable tragic accidents of x-ray soon produced many advisory and protective agencies.

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 nonultra sonic 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 the development of diagnostic systems of considerable practical value. Since the early days of the application of sonar principles in medicine, there have continually been 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.

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. In a large amount of documented data, no hazardous effects have been reported with low-intensity ultrasound energy up to now.

As mentioned, the field of ultrasonography has assumed such importance primarily as a result of the harmless nature of the modality. 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 for the opaque and injured eye. The pioneers of ultrasound, using only A-mode to combat the skepticism of their colleagues must have been exceptionally dedicated and patient. Scanning the eye and mentally integrating the A-mode spikes to give an answer to the clinician in need of a firm diagnosis must have produced great initial hope, but had a number of drawbacks due to inconsistency, time consumption, and interpretation. Many problems were alleviated by the introduction of B-mode scanning units. This technique was coupled with A-mode for optimal diagnostic information. After the development of the contact B-scan real-time scanner for ophthalmologic use, there have been sudden changes in sonography of the eye.

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.

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. Ultrasound, both as a screening and diagnostic modality, is a noninvasive and atraumatic procedure and is complementary to angiography and CAT scanning in many cases.

The information gained through ultrasound, as in other imaging procedures, is optimized when coupled with the patient's clinical picture.

The word "sonar" is an acronym of sound navigation and ranging. Historically, ultrasound was developed during World War I. Langevin 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. 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 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. The first ultrasonic instrument, called the supersonic reflectoscope, was introduced in 1940. 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.

When the prototype of the contact ultrasonic scanner became more popular since the transducer could now be placed on the patient's eye with direct contact, many further advances in equipment design became possible. Water-bath scanning of the eye was another technical development, and was soon followed by the application of time—motion displays.

By using two-dimensional real-time scanning systems, the eye dynamically can be evaluated in addition to detection and evaluation of their three-dimensional images.

At present, ultrasonography usage is spreading into many branches of medicine. It has become an integral part of many subspecialties, such as obstetrics, 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 that 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 opaque cornea and lens, it is virtually the only diagnostic tool available for visualization of vitreo-orbital disorders.

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ultrasonography

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