Ultrasonography of Pediatric Surgical Disorders

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ULTRASONOGRAPHY OF PEDIATRIC SURGICAL DISORDERS

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Grune & Stratton, Inc.
A Subsidiary of Harcourt Brace Jovanovich, Publishers
New York London
Paris San Diego San Francisco São Paolo
Sydney Tokyo Toronto

Library of Congress Cataloging in Publication Data

Canty, Timothy G.
Ultrasonography of pediatric surgical disorders.

Bibliography
Includes index.
1. Children—Diseases—Diagnosis. 2. Diagnosis, Ultrasonic. 3. Children—Surgery. I. Leopold, George R. II. Wolf, Deborah A. III. Title. [DNLM: 1. Diagnosis, Surgical—In infancy and childhood. 2. Pathology, Surgical—In infancy and childhood. 3. Ultrasonics—Diagnostic use. WO 141 C234u]
RJ51.U45C36 617'.07543 81-6803
ISBN 0-8089-1395-6 AACR2

Grune & Stratton, Inc.
111 Fifth Avenue
New York, New York 10003

Distributed in the United Kingdom by
Academic Press Inc. (London) Ltd.
24/28 Oval Road, London NW 1

Library of Congress Catalog Number 81-6803
International Standard Book Number 0-8089-1395-6

Printed in the United States of America

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ACKNOWLEDGMENTS

We would like to graciously acknowledge the help of many in the preparation of this book. The departments of radiology of several of our affiliated hospitals in San Diego, California, including Mercy Hospital, Children's Hospital, Scripps Memorial Hospital, Kaiser Permanente Hospital, and the Naval Regional Medical Center, were generous in providing us with the images for some of these cases. We wish to specifically thank Dr. Kenneth Miller of the Department of Radiology, Children's Hospital, San Diego, California; Dr. Saskia Hilton of the Department of Radiology of the Naval Regional Medical Center; and Dr. Daniel Weissberg of the Department of Radiology, St. Joseph Hospital, Orange, California. We further wish to thank Dr. David Collins, Dr. Randall Powell, Dr. William Brock, and Dr. George Kaplan—our colleagues and friends in pediatric surgery and uroloy in this community—for allowing us to include some of their cases in this book.

The authors would also like to express deep gratitude to the other members of the Division of Diagnostic Ultrasound, Department of Radiology, University Hospital, San Diego: William Scheible, M.D., Laura Schorzman, R.T., R.D.M.S., and Chris Skram, R.T., R.D.M.S., for their undying support in this project and for actually producing and interpreting many of the images utilized. The cooperation and expertise of the Division of Photography, Office of Learning Resources, University of California at San Diego School of Medicine, and photographers Donald Luczak and Daniel Ferro are greatly appreciated for their high-quality reproduction of the images for publication.

Lastly, we would like to give special thanks for the secretarial support of the Division of Pediatric Surgery, Department of Surgery, University of California at San Diego School of Medicine, including Sharon Palmer and, most importantly, Cynthia Baker, who single handedly typed and retyped this entire manuscript.

This project was undertaken with the overriding philosophy of increasing the communication, camaraderie, and working relationships between clinical disciplines and the disciplines of diagnostic imaging. We strongly feel that this book has represented for us an enjoyable, educational, and significant contribution to this end.

PREFACE

Advances in gray scale sonographic imaging techniques have occurred rapidly in recent years. The use of these techniques in clinical medicine for the initial diagnosis and serial follow-up of many important disease entities has blossomed as technological improvements have yielded better images of increasing numbers of organs and organ systems. The truly noninvasive sonogram may be the initial imaging technique of choice for many conditions since it allows for a more appropriate selection of the more invasive and/or radiation-dependent methods. The attractiveness of this technique to clinicians dealing with infants and children is obvious: it is noninvasive; it does not require radiation; and it does not hurt.

Whereas much of the initial progress in sonography has occurred in the adult population, the recent explosion of technology and information relating to the use of ultrasound for diagnosis in the fetus, infant, and child has firmly established ultrasound as a valuable tool in pediatric disease, much of which is surgical in nature.

The purpose of this book is to demonstrate to those physicians caring for infants and children—pediatricians, obstetricians, family physicians, and pediatric surgeons—the great clinical usefulness of sonography in both the diagnosis and follow-up of disease entities. This book also is directed toward general radiologists and specifically those interested in sonographic imaging, since it cogently and concisely presents the increasing body of knowledge in the field. An additional goal is to provide a clinically correlated sonographic reference and place sonography in perspective in relation to other imaging studies.

An attempt has been made to keep the format of the book uniquely consistent throughout. We have elected to use a regional/organ system of categorization, since this seems to be the most appropriate method of presenting clinical problems as they occur in practice. Much of the information presented is derived from our own experience at the University Hospital Medical Center in San Diego and its allied teaching institutions, as well as from pertinent reviews of sonographic data from other centers. The initial section of each chapter presents the clinical problems of a region of the body with reference to how the clinician who is confronted with pathology in this area might proceed with diagnostic evaluation. These sections are not meant to be exhaustive medical or surgical informational reviews, which are available in the many excellent texts of pediatrics or pediatric surgery. The following section illustrates the normal and abnormal sonographic anatomy of the area or organ system, discussing the merits and limitations of sonography for diagnosis of pathologic conditions. Specific technical aspects of sonographic imaging are also presented with an explanation of special considerations for that particular examination in children. Based heavily on our own experience, helpful hints for preparing the child for examination and actual conduct of the study itself are presented. Attention to such details makes the difference between a pleasant and successful examination versus an unpleasant technical disaster. Lastly, all of these topics are brought together by several actual case presentations in which the clinical problem is presented, the diagnostic procedures, including sonography, are carefully explained and illustrated, and treatment and follow-up are described. Specific comments are then made about the role and importance of ultrasound in each case.

The physical and technical aspects of ultrasonography are beyond the scope of this text and are well covered in several excellent sources that specifically deal with these areas. However, the initial chapter of this text does give a general overview of the emerging role of ultrasound in clinical pediatric practice, as well as a brief description of the various sonographic imaging techniques currently available. One chapter is also devoted to the rapidly expanding experience in antenatal diagnosis of many congenital anomalies of surgical significance. This has been a particularly exciting area that may greatly affect and improve the perinatal, obstetric, and surgical management of several life-threatening conditions.

As this book deals only with those pediatric problems that would be most likely handled by the general pediatrician and the pediatric surgeon, including genitourinary and pelvic disorders, it specifically excludes the large body of data in pediatric echocardiography and sonoencephalography, which are well covered in other monographs. It is hoped that this text will successfully provide a natural link between the clinical disciplines of pediatrics and pediatric surgery and the imaging discipline of ultrasound in a truly correlative fashion. Such an association will benefit infants and children by providing safer and more expedient diagnosis and treatment.

Contents

CHAPTER 1

ULTRASOUND: THEORY AND TECHNIQUES

The evolution of diagnostic imaging techniques has enjoyed steady progress since the advent of x-rays in 1895. Improvements and sophistications in conventional radiographic equipment have done much to reduce radiation exposure to patients and attending personnel, as well as improve image quality. Additionally, safe contrast agents and methods for imaging the GI tract, GU tract, the vascular system, and many other specialized areas have greatly expanded the usefulness of conventional x-ray-dependent imaging techniques.

Recently three new imaging modalities have appeared on the scene, each accompanied by an explosion of technical advances and new applications. These techniques are radionuclide imaging, computerized tomography (CT), and ultrasonography. Each modality has evangelical advocates proselytizing their methods as the one preferred for various conditions. As with any newly developed technique, there are growth and development periods, during which time the usefulness of the technique is scientifically documented, eventually replacing blind or naive enthusiasm.

In some instances, these modalities can and do work in complementary combination with one another; in others, one or another technique may emerge as the one of choice. The enthusiasm for the novel must be taken in the proper context of the objective of all imaging techniques: to produce, in as safe a fashion as possible, accurate information useful to the clinician in evaluating patients in both health and disease states such that proper diagnoses and appropriate therapies are instituted.

THE ROLE OF ULTRASOUND IN PEDIATRIC SURGERY

The pediatric clinician dealing with the day-to-day matter of evaluating and treating patients is confronted with a bewildering array of imaging techniques. Each has advantages, disadvantages, risks, and benefits. The clinician must have some way of choosing which one is appropriate for evaluation of a particular patient. In many cases a variety of techniques may give similar information. The tendency to overuse our extensive technology in an effort to be "complete" is quite obvious.

Surgical diseases in children not only result in significant and frequently life-threatening alterations in physiology, but are most often related to alterations of anatomy, either as a cause or result of the disease. There is thus a heavy clinician dependence on methods of accurately depicting normal and abnormal anatomy. It therefore becomes mandatory for those involved in imaging to have a good understanding of the needs of the clinician and the nature of the clinical problem; it is also necessary for the clinician to understand the advantages and limitations of various imaging techniques.

The importance of a close working relationship and continued communication between the clinician and the imager throughout the diagnostic evaluation plan cannot be overstressed. Sending a child to ultrasound (or any other imaging method) with an illegible scribble on a request form for "abdominal echo" is not only unacceptable but useless. Only through thorough interdisciplinary involvement and familiarity can both work successfully to achieve the desired result, i.e., producing useful images that appropriately assist the clinician in accurate diagnosis and treatment. It is a need for this kind of cooperation that forms the basis of this book.

It has become increasingly apparent with the rapid advances in sonographic imaging techniques that this modality is particularly well suited to children, in whom exposure to radiation, invasiveness, and compliance with the procedure are points of special importance. In many instances, sonography may be the preferred modality or may be used as the initial imaging technique to selectively guide the use of more invasive or radiation-dependent techniques. As many surgical lesions are masses, either solid or cystic, or dilatations, enlargement, or displacement of fluid-containing structures, ultrasound is especially appropriate for study of these children. Abdominal masses, hepatobiliary or genitourinary problems, and other tumors are often best detected by ultrasound. In contrast, the air-containing gastrointestinal tract is not favorably disposed to sonographic examination. Conventional radiation-dependent contrast studies still remain superior for this important organ system.

The prenatal use of ultrasound uncovers a variety of important surgical congenital anomalies prior to birth. The prenatal, natal, and postnatal management of many of these lesions has been profoundly affected by the antenatal knowledge obtained by ultrasound.

We therefore are launched into a new era of noninvasive, radiation-free imaging. Technological advances occur at such a rapid rate that much of what is written in this book will be improved upon, changed, or (in some cases) negated. This can, hopefully, be regarded as progress. However, it is important to hold in perspective the tremendous usefulness of this modality to the clinician caring for children. The remainder of this book is devoted to that task.

THE TECHNOLOGY OF ULTRASOUND

Dramatic advances in the development of diagnostic ultrasound instrumentation have occurred since 1975. Hand in hand with the progression of instrumentation has come the advancement and sophistication of the diagnostic capabilities of this noninvasive imaging modality. This section does not attempt to turn the reader into an "ultrasound physicist," but rather describes basic physical principles, and explains the various scanning modes and their use in relationship to ultrasound equipment. Emphasis is placed on the examination of the pediatric patient, as well as the provision of a guide for the selection of instrumentation catering to the child in specific clinical settings.

Biological Effects of Ultrasound

A common and legitimate concern of both parents and clinicians is the question of biological effects and potential harmful consequences of ultrasound to the pediatric patient. Diagnostic ultrasound has been reputed for many years to be a noninvasive technique. The literature reviews many studies of continuous and pulsed ultrasound and their effects on human tissue. Chromosomal analysis after exposure to continuous wave ultrasound has led to differing results as to whether or not actual damage is caused. No negative effect from pulsed ultrasound on human cells has been documented thus far.[1] It is a pulsed ultrasound beam that is utilized for most diagnostic purposes (Doppler techniques utilize continuous-wave ultrasound). A transducer emitting pulsed ultrasound is active less than 0.1 percent of the time; the remainder of the time is used for receiving echoes. Thus, if an examination requires fifteen minutes actual scanning time, the child has received a total of 0.9 seconds of sound wave exposure.

Soundwaves and Ultrasound

Medical diagnostic ultrasound equipment produces soundwaves electrically by stimulating a piezoelectric crystal. The original description of the piezoelectric effect by Pierre and Jacque Curie in 1880 utilized a quartz crystal.[2] Synthetic ceramic crystals have now been found to be superior for sound wave production for medical diagnostic purposes. A rapidly alternating electric current is applied by a transmitter across the ceramic crystal, causing it to vibrate at its resonant frequency and an ultrasound beam is produced. The piezoelectric principle allows the same crystal to receive soundwaves and generate small electrical potentials, which can then be processed by a receiver. The piezoelectric crystal thus acts not only as a sound wave generator but as a receiver, forming the basis of the *pulse–echo technique* used in diagnostic ultrasound. The crystal is conveniently housed in a small cylindrical hand-held instrument, the transducer, which comes into contact with the patient's skin while emitting and receiving soundwaves. There are many transducer characteristics which must be considered in their selection. Selection of transducer frequency and size are the major considerations for the pediatric population. Medical ultrasound commonly utilizes soundwaves in the frequency range of 1 to 10 megahertz (MHz). For the pediatric population, 3.5–10 MHz (short and medium focus) are the frequencies employed. The higher the frequency, the greater the resolution, and the lower the depth of penetration. Thus, the overall size and depth of the portion of the body to be examined rules frequency selection. For example, a 10 MHz transducer will be superior in the examination of neonatal kidneys, located quite close to a thin body wall, but inferior for an adolescent, where the kidneys are more deeply located with respect to the scanning surface.

Of the various scanning modes used for clinical purposes, B-mode presentation consists of a two-dimensional, cross-sectional display and is a tomogram. It can be produced in any plane desired, such as longitudinal, transverse, or special views. The images are displayed in "gray-scale": a color coding ranging the spectrum of white to black. The shade of gray dot formed on the screen is dependent upon the various acoustic properties of tissues. In general, strong echoes (reflections) are received from the boundary of organs, and weak ones from its parenchyma. Structures which are homogeneous show little echo return from within, while those with heterogeneous texture will exhibit considerable internal structure. All illustrations in this book are B-mode gray-scale images reproduced from either static or real-time images. Static images are usually transferred to radiographic film; real-time images may be videotaped for permanent storage.

CURRENT ULTRASOUND EQUIPMENT

Contact Static Scanner

The contact static B-mode scanner produces single plane two-dimensional images (tomograms) which are viewed at the time of examination on a television monitor. The production of the image is dependent upon the technical expertise of the operator and cooperation of the patient (Fig. 1–1). The contact static scanner will produce superior quality images in the ideal setting. As they are static "pictures," they do require the limitation of motion during the exam (Fig. 1–2). Diagnostic scans of the pediatric patient may often be more easily acquired by utilizing real-time instrumentation, which is less affected by patient motion (Fig. 1–3).

Real-time Scanner

Real-time instruments also produce tomographic images in gray-scale. The unique features of displaying motion and rapid, automatic scanning in any plane usually enhance and expedite the examination of the younger pediatric patient (Fig. 1–4). The transducers

Fig. 1–1. A contact static scanner is utilized on this 9-year-old child positioned for supine longitudinal scans of the upper abdomen. The images are viewed simultaneously on a television monitor.

Fig. 1–2. The upright position is one of the many useful positions for either real-time or contact static scanning. The child may either sit or be held by a parent in the position while the transducer is directed over the posterior body wall. This position is ideal for the localization of fluid in the supra- or sub-diaphragmatic spaces, as well as for visualization of the kidneys. (Static scanner shown here.)

Fig. 1–3. The versatility of the real-time unit is depicted on this 3-year-old child reclining in the right lateral decubitus position. The small scanning head is easily directed between the intercostal spaces for visualization of the spleen and left kidney. Respiratory motion does not affect the image quality. The "automatic–continuous" scanning capabilities of real-time allow the sonographer to follow the area of interest.

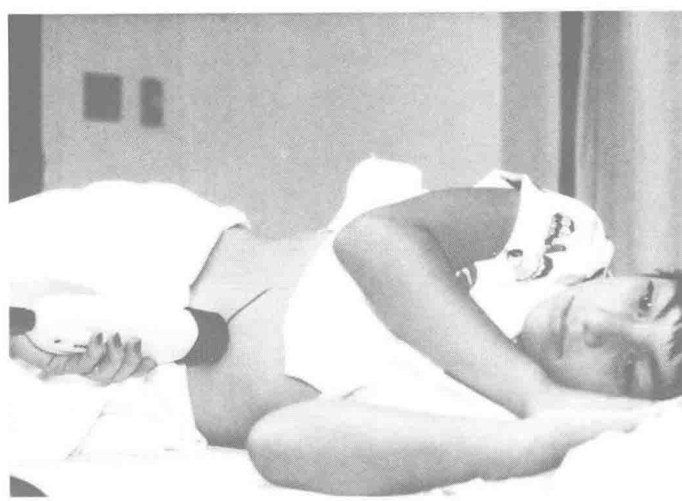

Fig. 1–4. Real-time scanners are superb for following the paths of tubular structures, as demonstrated here with a 9-year-old child in the right anterior oblique position. The sonographer is searching for the extrahepatic biliary ducts. A black wax pencil mark indicates the approximate plane of the ducts and portal vein. The exact location varies slightly from patient to patient.