ULTRASOUND OF THE PEDIATRIC ABDOMEN AND PELVIS

A CORRELATIVE IMAGING APPROACH

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YEAR BOOK MEDICAL PUBLISHERS, INC.
CHICAGO•LONDON

Library of Congress Cataloging in Publication Data

Kangarloo, Hooshang.
Ultrasound of the pediatric abdomen and pelvis.
Includes index.
1. Pediatric gastroenterology—Diagnosis.
2. Pediatric urology—Diagnosis. 3. Diagnosis, Ultrasonic. 4. Abdomen—Diseases—Diagnosis.
5. Pelvis—Diseases—Diagnosis. I. Sample, William Frederick, 1939–1979 joint author. II. Title.
[DNLM: 1. Abdomen. 2. Pelvis. 3. Diagnosis—In infancy and childhood. 4. Ultrasonics—Diagnostic use. WS310 K16u]
RJ449.U45K36 617'.55'0754 79-25906
ISBN 0-8151-4972-7

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Preface

EVALUATION OF DISEASE PROCESSES in the abdomen and pelvis requires a thorough understanding of the various imaging modalities available for assessment of pathological states. Recent advances in ultrasonography and computerized tomography have made it possible to establish a diagnosis faster and more accurately, but careful study of the application of these newer modalities is needed to prevent either excessive or inappropriate use.

The purpose of this text is to provide a correlative approach to the evaluation of abdominal and pelvic diseases in children as well as to assist in the selection of the best modality for establishing a diagnosis in the shortest period of time, at the lowest cost, and with the least harm to the patient.

Ultrasonography, because of its noninvasive and flexible nature, is one of the most acceptable modalities for the evaluation of disease processes in children and has received the main emphasis in this book. Ultrasonography has long passed the era of being limited to making the distinction between solid and cystic processes. It can frequently provide exact anatomical location and sometimes an accurate histological diagnosis. It is our intention to familiarize the reader with the detailed anatomy of the pediatric abdomen and pelvis and to review a spectrum of various disease processes in these areas. Since it is important to understand why we see what we see, each chapter begins with a description of particular pathological processes, which is then followed by appropriate illustrations. The illustrations are labeled in order to facilitate a grasp of the three-dimensional anatomy of the abdomen and pelvis.

We are thankful for the contributions of the following: Dr. Gary Amundson, who has been coauthor for chapters 2–10; Dr. Dennis Sarti, who contributed chapter 1; Dr. Gail Hansen, who provided the text for chapters 11–14; and Dr. Donald Rose, who provided the nuclear medicine studies and their interpretations.

We are indebted to many Residents and Staff of the UCLA School of Medicine for their strong support and stimulation during the preparation of this text. Anne Von, our secretary, in particular took a personal interest in this project and the final copy of the book emerged from her desk. She was assisted by three other secretaries who devoted time and energy to its preparation: Kathleen Ann Heitman, Marion M. Flowers, and Mary P. Frazier. We are in their debt. Georgia Keris, our very helpful librarian, provided all of the references and kept everything organized. We cannot thank her enough. We are especially grateful to Kimberly Willis, who produced all the illustrations, and any success this book may have will largely be because of her excellent job. We are also thankful to the supervisor of our photography lab, Paul E. Stout. For the quality of the images, we owe a special note of appreciation to the technologists in Ultrasound and Pediatric Radiology, and especially to Robert E. Clark and Rosemary Kozlowski. We also thank Jean Slater and Carol Mancel for their contributions. We are

deeply grateful to our Chairman, Gabriel H. Wilson, M.D., and our Vice-Chairman for Education, Elias Theros, M.D., for their continuous encouragement and support of various projects. Last, but definitely not least, we are thankful to the Year Book Medical Publishers and their staff for their understanding and excellent advice. Without their personal interest, this project would have been impossible.

HOOSHANG KANGARLOO, M.D.

Acknowledgments

Acknowledgment is made to the following individuals and publishers for use of various illustrations in this text.

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Figure 1–14: Courtesy of Dr. Richard Hoffman, Torrance, California.

Figure 1–16: Courtesy of Dr. Roy Filly, San Francisco, California.

Figures 2–11 to 2–20: Kangarloo, H., Sukov, R., Sample, W. F., Lipson, M., and Smith, L.: Ultrasonographic evaluation of juxtadiaphragmatic masses in children, Radiology 125:785, 1977.

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Figures 10–61 and 10–62: Courtesy of Dr. Ross Eto, Santa Monica Hospital, California.

Figure 11–25: Courtesy of Dr. Michael T. Gyepes, Long Beach Memorial Hospital, California.

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Contents

1

Prenatal Anatomy and Anomalies

THE MOST DYNAMIC TIME of our lives occurs from conception to delivery; growth is rapid and future development is dramatically determined by those initial 9 months. Yet limited means are present that provide insight and information on this crucial time. The development of diagnostic ultrasound has provided a technique by which we can follow the progress of a developing fetus. This technique has improved in recent years, providing information and images during pregnancy that have helped us understand and monitor the growing fetus.

This chapter will deal with the fetus. Although the placenta, uterus and maternal anatomy are most important to pregnancy, they will not be discussed in this chapter. Instead we will concentrate on the normal and abnormal ultrasonic appearance of the developing fetus.

Diagnostic ultrasound was first used in examining the obstetrical patient in the late 1960s, with a "bistable" technique that recorded echoes from strong specular reflectors and yielded outlines of organ structures. The development of gray-scale echography has permitted recording of weaker reflectors arising from parenchymal tissue. This, along with improved transducer design and focusing, has produced images of markedly improved resolution and quality.

TECHNIQUE

Obstetrical studies are usually performed on a B-scan or real-time unit. A 3.5-MHz transducer, 13 or 19 mm in diameter, is used for most patients undergoing B-scan examination. Occasionally, a 2.25-MHz transducer will be necessary for increased penetration, especially on the obese, near-term patient.

Real-time examination is most often performed using a linear array, 2.25- or 3.5-MHz transducer. This provides an advantage over a "static" B-scan examination in that fetal activity can be assessed and monitored. This is of importance in ruling out fetal death or determining fetal extremity motion. Real-time examinations are also more quickly performed than B-scan studies. However, real-time images do not presently have the resolution of B-scan images. The patient is usually studied using the full-bladder technique, which serves 2 major purposes. First, it lifts the small-bowel loops out of the pelvis. This is extremely important in early pregnancy since air-filled bowel loops can completely obscure the uterus. Second, in later pregnancy a filled urinary bladder will provide better visualization of the lower uterine segment as it elevates the uterus out of the pelvis.

GESTATIONAL AGE

Accurate determination of gestational age is extremely helpful to the obstetrician in monitoring pregnancy. Ultrasound provides a means of assessing gestational age by measuring 3 rapidly growing anatomical structures: (1) mean diameter of gestational sac, (2) crown-rump length (CRL) and (3) biparietal diameter (BPD).

From the 5th to 11th menstrual week of pregnancy, gestational age can be determined by measuring the mean diameter of the gestational sac. The sac is first visualized in the uterus at the 4th–5th menstrual week as a circular to oval, highly echogenic region with central sonolucency. This undergoes rapid growth, with an increase in diameter of approximately 7–10 mm per week. By the 10th menstrual week it is 5–6 cm in diameter. The surrounding high-amplitude echoes of the gestational sac are formed by the lace-like vascular network of the chorionic villi and decidual reaction. The gestational sac eventually disappears around the 11th menstrual week as the chorionic villi, which are opposite the placental implantation site, atrophy. However, the rapid growth of the gestational sac from the 5th to the 11th menstrual week provides an excellent measurable anatomical structure for assessing gestational age.

From the 6th to 15th menstrual week, the CRL can be measured by ultrasound to estimate gestational age. Its rapid growth from 7 mm to approximately 8 cm during this time provides an excellent means for dating the pregnancy. A major difficulty in obtaining a CRL is the marked activity of the fetus during early pregnancy. It is easier to obtain a CRL using real-time ultrasound since fetal activity can be dynamically monitored and a quick scan parallel to the long axis of the fetus obtained.

After the 15th week of pregnancy, gestational age is determined by measuring the BPD, which is the widest distance between the parietal bones. The BPD should be visualized in 100% of pregnancies by the 15th menstrual week. It can occasionally be obtained as early as the 11th or 12th week. The BPD grows approximately 3 mm per week in the 2d trimester. Therefore, the earlier in pregnancy that one obtains the BPD, the more accurate the assessment of gestational age.

Several sources of error can arise in obtaining a BPD. Variation in technique among ultrasonographers leads to a large source of error. It is important to use a reproducible technique, such as that described by Campbell (1968, 1969), in obtaining the BPD. Fetal activity and position are also sources of error.

Since the 3 anatomical structures just discussed are easily identified by ultrasound, they can be measured at various appropriate times during pregnancy to give an estimate of gestational age.

NORMAL FETAL ANATOMY

The embryo is first visualized by present-day ultrasound equipment at approximately the 7th menstrual week. As the fetus enlarges, numerous anatomical structures can be seen in the 2d and 3d trimesters. Besides the skull and falx cerebri, numerous other structures of the fetal head can be identified, such as lateral ventricles, thalamus, 3d ventricle, corpus callosum, foramen magnum, middle fossa and bony orbits. Structures of the normal fetal thorax and abdomen that can be visualized include ribs, heart, lungs, aorta, inferior vena cava, spine, kidneys, spleen, stomach, urinary bladder, umbilical vessels, bowel, scrotum and penis. The various bones of the upper and lower extremities can also be identified. It becomes extremely important to recognize normal fetal anatomy in order to detect abnormal fetal detail during a routine obstetrical study.

AMNIOCENTESIS

Ultrasound has proved of assistance in patients undergoing amniocentesis for fetal karyotyping, sexing, α-fetoprotein (AFP) levels, lung maturity and serial evaluation of Rh-sensitized pregnancies.

The primary use of ultrasound in these instances is to locate a readily accessible pool of amniotic fluid. However, it also provides other important information, such as (1) gestational age, which aids in AFP determination, (2) the presence of twins and tap sites for sacs, (3) fetal death, which can elevate AFP and (4) gross fetal abnormalities. When chemical studies from amniocentesis are found to be abnormal, it is advisable to reexamine the patient and perform a thorough fetal study.

ABNORMALITIES OF THE FETAL HEAD

The fetal head is easily recognizable during routine ultrasound examination in 100% of normal pregnancies after 15 weeks' gestation. Anencephaly, microcephaly, hydrocephalus, encephaloceles, posterior fossa cysts and cystic hygromas have all been detected by ultrasound. The AFP levels in amniotic fluid decline from 2 mg/dl at 12 weeks to less than 0.5 mg/dl at 20 weeks. An elevated AFP level may be caused by neural tube defects. This should lead to close scrutiny of the fetal head. Anencephaly yields a markedly elevated AFP level and can be easily recognized by ultrasound. A cluster of echoes is found in the region of the suspected fetal skull. Very often the fetus is quite active and hydramnios is present secondary to interruption of the fetal swallowing mechanism. Microcephaly is more difficult to detect. Comparison of the relative size of the fetal head to fetal body can assist in the early detection of microcephaly.

Ultrasonic visualization of an enlarged or abnormally sonolucent fetal head has been noted in hydrocephalus and posterior fossa cysts. Sonolucent masses adjacent to the fetal skull can be seen in encephaloceles, meningoceles and cystic hygromas. Such abnormalities within and about the fetal skull are usually detected when one is attempting to obtain a BPD for gestational age. Real-time examination is often quite helpful in detecting such an abnormality since a three-dimensional concept of the fetus can be derived quite quickly.

SPINAL ABNORMALITIES

Since an elevated AFP level is often secondary to a neural tube defect, close examination of the fetal spine is also necessary. Spinal abnormalities, such as meningoceles, meningomyeloceles, spina bifida and sacrococcygeal teratomas, have been reported. The fetal spine can be easily identified with present-day equipment in both longitudinal and transverse sections. A longitudinal scan slightly anterior will display the tubular aorta. Transverse scans of the fetal spine demonstrate a highly echogenic area surrounding a central sonolucent region situated in the posterior aspect of the thorax or abdomen. When the AFP level is elevated, close scrutiny of the region posterior to the cervical and sacral spine is undertaken to rule out the presence of any masses secondary to meningoceles and meningomyeloceles. The fetal spine is also examined in the transverse plane in an effort to detect any posterior defects suggesting spina bifida. Finally, real-time examination of the lower extremities is performed to detect normal motion.

ABNORMALITIES OF THE FETAL ABDOMEN

As mentioned earlier, some sonolucent areas are normally present in the fetal abdomen. When they are too numerous or large, closer examination is necessary to rule out a pathological state. High gastrointestinal tract obstruction involving the stomach, duodenum or proximal part of the jejunum will produce large sonolucent masses in the upper part of the abdomen, accompanied by hydramnios. Interruption of the normal fetal swallowing and absorption mechanism will lead to hydramnios, as is the situation in proximal gastrointestinal tract obstruction. Mesenteric cysts have been visualized by ultrasound in utero and appear as sonolucent abdominal masses. When fluid-filled abdominal masses are noted in the presence of oligohydramnios, a genitourinary tract abnormality should be considered. Hydronephrosis, megaureter, obstructed upper-pole calix secondary to ectopic ureterocele and fetal polycystic kidney disease have been reported. If multiple abdominal fluid masses are present, the fetal renal beds should be examined closely in an effort to identify the fetal kidneys. This is especially necessary in the presence of oligohydramnios. Abdominal fluid present within the peritoneal cavity and not within bowel loops has also been identified. Fetal ascites is most often seen in Rh sensitization and has an ultrasonic appearance similar to that seen in the adult. The fluid is not contained within bowel loops. It is located peripherally, with bowel loops and liver displaced centrally.

THORACIC AND SKELETAL ABNORMALITIES

Examination of the fetal thorax is most often concerned with fetal cardiac activity to document fetal viability. However, fetal echocardiography is being performed in an effort to detect cardiac anomalies. Pleural effusions appear as fluid within the pleural space similar to that seen in the adult. A collapsed or "empty" thorax is manifested in fetal death as a relatively lucent thorax with distortion of the normal architecture.

Evaluation of proximal to distal extremity length and the relative size of the extremities in relation to the fetal head and body have been undertaken. This has raised the possibility of intrauterine diagnosis of skeletal abnormalities. Thanatophoric dwarfism and chondroectodermal dysplasia (Ellis-van Creveld syndrome) have been reported.

INTRAUTERINE GROWTH RETARDATION

The early diagnosis of intrauterine growth retardation (IUGR) is of importance since the fetus will be delivered as soon as lung maturity is present. The fetus will do better outside the uterus once lung maturation is present. Since IUGR results in higher perinatal mortality and morbidity, early diagnosis is critical. Leveling growth rate of the BPD has been used to detect IUGR. However, this will detect only 50% of affected fetuses. The reason is that 2 patterns of growth retardation have been noted. In the first, or diffuse, type, the entire fetus is small and the BPD will not grow at the usual rate. In the second, the fetal head is spared at the expense of the body and the BPD may appear normal throughout pregnancy. Because of this finding, total intrauterine volume (TIUV) is more useful in detecting IUGR. The TIUV takes into account the fetus, placenta and amniotic fluid in detecting IUGR and has proved more sensitive than the BPD alone.

FETAL DEATH

Numerous ultrasonic findings should alert the ultrasonographer of fetal distress or death. A "double ring" sign about the fetal head or body is indicative of fetal edema. It can be seen in Rh sensitization, congestive heart failure and 24–48 hours after fetal death. Ultrasonic visualization of overlapping skull bones indicates fetal death and degeneration. Marked tortuosity and angulation of the fetal spine can occasionally be demonstrated by ultrasound and roentgenograms when fetal death occurs. Since ultrasound detects acoustical interfaces, separation of the amnion from the chorion can be easily demonstrated and can suggest fetal death. Lack of fetal activity during the course of a routine B-scan examination should alert one to the possibility of fetal difficulty.

When any of the above findings are present, examination for fetal viability by either real-time or Doppler is necessary. Fetal viability can be quickly determined by locating the fetal thorax and documenting cardiac activity.

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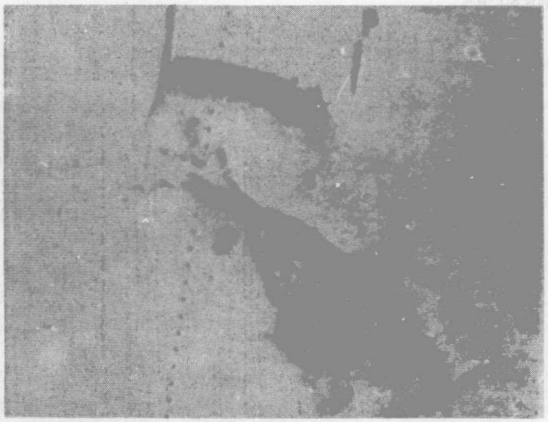
Fig 1–1.



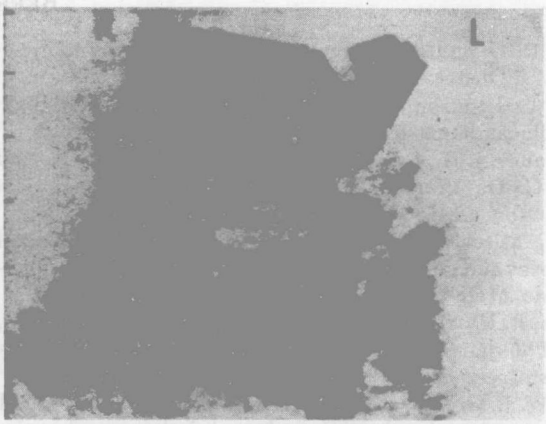


Fig 1–2.

Fig 1–3.

Fig 1–4.

Figs 1–1 to 1–4.—Gestational age. Ultrasonic determination of gestational age is obtained by measuring 3 easily recognizable structures at different times of pregnancy. In early pregnancy, from 5th to 10th week, determination of mean diameter of gestational sac gives estimate of gestational age. In Figures 1–1 and 1–2, length (L), height (H) and width (W) of gestational sac are added and then divided by 3. Mean diameter of gestational sac grows from 1 cm at 5 postmenstrual weeks to approximately 5 cm at 10–11 weeks. P = symphysis pubis; B = urinary bladder; R = toward right of patient; L = toward left of patient.

Crown-rump length (CRL) is 2d measurement used to determine gestational age. This is most often used from 7th to 14th week of pregnancy. Figure 1–3 is an example of CRL determination that measures distance from fetal crown (C) to fetal rump (Ru). This measurement can often be difficult to obtain on B-scan unit secondary to fetal activity. This problem is overcome with real-time ultrasound, which enables more rapid determination of long axis of fetus. H = toward head of patient; F = toward foot of patient; Pl = placenta.

From the 15th week until term, gestational age is determined by measurement of fetal biparietal diameter (BPD). The BPD should be identifiable in 100% of cases by 15 weeks and can often be seen as early as 11 or 12 weeks. The measurement in Figure 1–4 is obtained from near fetal skull (FS) to far fetal skull echoes once appropriate midline structures are identified. It is necessary not only to identify linear midline echoes of falx cerebri and 3d ventricle but also the relatively lucent thalamic regions (Th) in order to be certain you are at correct level. The BPD grows 3 mm/week up to 30–32 weeks and then decreases its growth rate to 1–2 mm/week until term. Therefore, a more accurate determination of gestational age from BPD is obtained earlier in pregnancy.