HANDBOOK OF INTRODUCTORY ABDOMINAL ULTRASOUND FOR WEST AFRICA

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A HANDBOOK OF INTRODUCTORY ABDOMINAL ULTRASOUND FOR WEST AFRICA

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DEDICATION

The work is dedicated to patients whom ultrasound scan or procedure will be or was beneficial.
FOREWORD TO HANDBOOK OF ABDOMINAL ULTRASOUND

While I was in training in the mid 1960s, Ultrasound was restricted to A- mode display of the midline shift of the falx cerebri using the sonographic equipment called encephalogram for the procedure called Encephalography. But the only centre that went beyond this was that of Ian Donald in Glasgow where his team had started the use of B-mode ultrasound in Obstetric and Gynoecology. They were to pioneer the use of Biparietal Diameter (BPD) as the most accurate means of determining the gestational age of the growing foetus in utero. Their table of measurements was later to become the gold standard.

In the early 70s, the equipments were beginning to come into the market which performed ultrasound (US) in the A, B and M modes. For me my first introduction into clinical ultrasonography was during my study leave from June to September 1972 at the Radiological Department of the McMaster University Medical Center (MUMC) in Hamilton, Ontario, 40 miles (64 km) south of Toronto and the same distance West of Niagra Falls. My host was Professor W.Peter Cockshort, the pioneer Chairman of the new Radiology Department since he left Ibadan in 1967 after 10 years of pioneering academic Radiology in West Africa. My study leave was sponsored by the University of Ibadan and a grant from the Canadian International Development Agency (CIDA). The MUMC was an architectorial master piece shaped like a luxury liner and a luxury hotel combined had just been completed. The Radiology Department was a tourist attraction. The latest in Radiology equipment was being installed and test run in anticipation of the first patients just like Cockshott had experienced in January April 1957 at the UCH Ibadan. I had to go twice weekly to the St Joseph's Hospital down town to spend the day at the Ultrasound Unit attached to the Obstetric and Gynoecology Department. The equipment in use was the ECHOVIEW 6, a product of the dominant Radiology Equipment Company then, the Picker Corporation of North America. I say dominant because every where we went in Canada and the USA the green coloured brand logo of Picker was seen in Radiology Departments. But alas, almost a decade later, in 1981, the company had been displaced by competitors notably Philips of Einthoven, Holland; Siemens of Ehlanger, Germany, GEC of Wembley, UK; CGR of Paris, France; Toshiba and Shimatzu of Tokyo, Japan.
When I was back home, I wrote a memo to the UCH Administration, which I got signed by 8 other departments who will benefit from the Hospital having an ultrasound equipment of the same make. The Echoview 6 was ordered through the firm of Watson & Sons (Electromedical). It was delivered in 1975 and became the first Ultrasound Equipment in Nigeria and West Africa. The scan is done using an articulated 3 parts arm which is shaped like a letter N full flexion and Z on full extension. During scanning it moves with along a longitudinal tract, making a syncopated ker ker ker ker sound like a Gieger Mueller counter at scintigraphy while holding to the transducer (probe) hinged to the end of the arm to steady it. It was cumbersome to operate. The image was a series of dashes and dots in white on a black background in which squares 1cm apart were ruled in white each representing a distance of 10 cm on the body surface or the image of the organ being scanned. The BPD of a foetal skull could be estimated roughly by counting the squares! The image is recorded by a Polaroid camera attached to the monitor and swung into place to make a snapshot followed by pulling out the exposed film to display the picture as it evolves it dries in ones hand. Some six months after delivery, a new model came into the market. This incorporated the new technological advance the so-called GREY SCALE and with it REAL TIME images. I felt very upset. In North America, the new model would have been delivered or the old model traded in and scrapped. We were landed with a model that took two years to arrive due to bureaucratic encumbrance in budgeting, ordering, shipping, clearing and delivery. At the Association of Radiologists of West African (ARAW) conference in Ile-Ife in 1983, a new company, registered in Nigeria as Associated Electronic Products Nigeria Ltd (AEPL), a subsidiary of Dutch company, Philips of Einthoven, Holland, had a display of the latest product in Ultrasound. This is the Sonodiagnost 1000. It featured Grey Scale Real time images. There were two detachable transducers on a flexible cable allowing the scanning to be done manually by the operator. The images were so sharp permitting identification of organs like liver, spleen, kidneys, uterus, pancreas, ovaries, gallbladder and urinary bladder with their distinctive parenchyma and boundary images on the grey scale which we could not achieve with the former Picker Echoview 6 equipment. Fortunately, the Head of the Medical division of AEPL, was Mr Somoye, the former Chief Radiographer of the Radiodiagnosis Department at LUTH, was the exhibitor. He confided in me that the equipment was ordered for a hospital in Lagos who could not pay and they were stock with it. That was how the Philip Sonodiagnost 1000 came to UCH. It revolutionised the practise of Ultrasound Examination in the Hospital pushing its predecessor into obsolescence. Within the first year of its acquisition, over 2000 examinations were done. It was in daily demand by several departments and units especially Obstetrics & Gynoecology (O&G), Surgery, Paedritrics, Nephrology and Cardiology. It virtually eliminated the request for X-ray examinations of the pregnant abdomen and the hepatobiliary system. Moreover it generated revenue so fast for the hospital that the cost of acquisition was recovered in no time.
We experimented with the use of groundnut (peanut) oil bought from the local markets in Ibadan as the coupling medium instead of the aqua jell supplied. We found it worked. We continue to use this medium for the next three years. It was sold in bottles and had been used as body lotion and traditional oil by women plaiting their hair in the traditional fashion from ancient times. A supplier of the jell was able to induce the department to change over to his stock by given a large bottle free after it was alleged that the probe rubber had been chewed by a rat which no one saw or captured. From thence the jelly came back to use and that was the end of the groundnut oil application as a coupling medium for ultrasonography.

On 20th November 1987, the UCH Ibadan marked the 30th Anniversary of its official opening to the public. Although patients were first admitted in May 1957, the formal ceremony of commissioning the Hospital, was performance by Princess Alexander of Kent on behalf of Her Royal Majesty, Queen Elizabeth II who was in Nigeria on the occasion of the grant of internal self Government to the Western and Eastern Regions of Nigeria as a prelude to the granting of Independence to Nigeria by 1st October 1960. The UCH Board of Management used the 30th Anniversary Celebration to launch an Appeal Fund. Among the companies invited to the events was the First Foundation Medical Co Ltd who had just been appointed as the Sole Agent in Nigeria for the marketing and servicing of Siemens Radiological Equipment. Before this time the agency was held first by Watson & Sons (Electromedical) and later Philips Medical. On display at the Exhibitions by various departments and companies in the School of Nursing courtyard was the latest Ultrasound equipment by Siemens of Erhlangen, West Germany. I appealed to the Manager of First Foundation to request the Head Quarters to donate the Equipment to UCH as part of its response to the Appeal Fund. I asked him to remember that in 1966, their Government had donated a polydirectional tomographic equipment, the Siemens Multiplanigraph to the UCH. That equipment was to be used between 1968 and 1980 for the Radiological Examination of Diseases of the Ear with particular reference to Congenital Deafness in additional to its use for general radiography. Our department becomes known as the only centre in Africa and one of the few Radiology centres world wide publishing on the Tomographic evaluation of diseases of the hearing apparatus in the days before CT came to displace it. The author they would recall had an Exhibit on Tomography of the Petrous Bone in diseases of the ear in the African at the 2nd Asiatic & Oceanian Congress of Radiology in Manilla, Phillipines, on invitation of the organisers and pictures comparable to what was obtained by the earlier equipment the Polytome by their competitor Philips was demonstrated on the Siemens multiplanagraph. The request was granted and the Ultrasound Equipment was delivered in February 1988.
In 2001, the RSNA initiated the “train the trainers” programme to assist developing countries especially Africa under Professor Barry Goldberg. About five radiologists from Africa were trained most of whom I recommended. One of the authors of this book is a direct beneficiary of the programme.

The handbook of Abdominal ultrasound has given an overview of the subject by experienced radiologists from the West African region. As the editors emphasised in the preface, the book is meant for beginners. It is not meant to be an atlas of the various pathological states. It is hope that they would publish a fuller edition at a later date for the benefit of the practitioners of ultrasonography that have multiplied into thousands since the apparatus was introduced into West Africa in 1975. I am happy to recommend the book for use in medical centres throughout the Region.

Professor SB Lagundoye
UCH, Ibadan, Nigeria
Figure 1a. The Echoview 6 ultrasound machine ordered through the firm of Watson & Sons (Electromedical) to UCH Ibadan. It was delivered in 1975 and became the first Ultrasound Equipment in Nigeria and West Africa.
(Courtesy of Professor SB Lagundoye)

Figure 1b. The first image of the kidney with Echoview 6 ultrasound machine above.
(Courtesy of Professor SB Lagundoye)
PREFACE

The idea of the book began one evening during the West African College of Surgeons, Faculty of Radiology examination in April, 2007, while discussing with Dr Len Gordon Harris of Sierra Leone regarding our lack of interest on documenting the medical cases we see commonly in the West African region in form of books. Both of us agreed to write a book on abdominal ultrasound being the most commonly requested ultrasound examination in our environment. On return, I discussed with Professor Tahir Abdurahman, who gladly accepted the idea. He advised that experts in the field of ultrasound be included across the region.

The book is mainly an introductory reference text intended to lay a good foundation for beginners in abdominal ultrasound. Relevant images are included to improve visual understanding to a beginner. Similarly, emphasis was made to common conditions that are seen in day-to-day ultrasound practice in our environment. Detailed or in-depth descriptions or rare cases were not included. It comprises of eight chapters from physical principles of ultrasound to ultrasound of abdominal organs like the liver, gallbladder, spleen, pancreas, urinary system, gynaecology and the abdominal vasculature. Each of the chapters follow a structured format outlined below for uniformity and ease of understanding: Introduction, Sonographic anatomy, Relevant physiology (where applicable), Sonographic technique, Ultrasound findings in common diseases in the West African sub-region—which was discussed as congenital or acquired. The acquired conditions should also follow a structured format i.e., infective/inflammatory, tumors, vascular, traumatic, etc for easy understanding. Differential diagnosis of common ultrasound patterns were offered where applicable. Each of the chapters was written by a renowned expert in the field.

We wish to thank the contributors of the chapters, the entire staff of the Radiology department, University of Maiduguri Teaching Hospital and Mr and Mrs Gaza for painstakingly publishing the work.

The book is intended to serve as breakfast for students and ultrasound users. It teaches the beginner the relevant information he needs before embarking on ultrasound, how to perform the procedure and necessary information required with regard to the findings.

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XI
INTRODUCTION
Ultrasound has seen many applications in the past in the detection of submarines and charting of contours of the sea bed before it became available as a medical equipment to “see through” the human body. Availability of state-of-the-art engineering and computer technologies has now led to wide use of medical ultrasound machines capable of producing detailed two- and three-dimensional images.

A typical basic ultrasound machine uses sound waves with frequencies above the range of human hearing to produce images of the parts of the body under examination. It is essential to understand the physical principles that are relevant to the production and interpretation of ultrasound images.

Transducer: The Ultrasonic Beam Source
The audible sound waves that the human ear can perceive have frequencies ranging from 20 Hz to 20 kHz. The inaudible ultrasonic sound wave frequencies used in medicine are much higher than 20 kHz and are typically between 1 and 15 MHz. These inaudible sound waves are generated and received by a transducer probe, an important component of the ultrasound machine, using a principle called the piezoelectric or pressure electricity effect.

When an electric current is applied to the piezoelectric crystals in the transducer probe, it causes rapid vibrations of the crystals, which produce sound waves that travel outward into the human body. In the reverse, when the returning sound waves from the inner part of the body hit the crystals, they produce electrical currents, which are converted to visible image. The transducer probe, in converting electrical energy into sound energy and vice versa, thus behaves like any other typical transducer, which is any device that is capable of converting energy from one form to another. Its capacity to make the sound waves and receive the returning echoes from the organ of interest in the human body also makes it the mouth and ears of the ultrasound machine.

Transducer probes come in many shapes and sizes, as shown in Figure 1.1. The shape of the probe determines its field of view, and the frequency of the emitted sound waves determines how deep the sound waves penetrate and the resolution of the image.
Some transducer probes can be moved across the surface of the body. Others are designed to be inserted through various openings of the body, such as vagina, rectum and esophagus, so that they can get closer to the organ under examination like the uterus, prostate gland and stomach to allow for more detailed views.

**Properties of Ultrasound as a Mechanical Wave**

The propagation of the ultrasound waves given off by the transducer probe occurs in the form of a longitudinal wave, which is a mechanical displacement in the same direction as propagation. The longitudinal sound waves are transmitted as an alternation series of compressions or zones of high pressure and rarefactions or zones of low pressure as shown in Figure 1.2.
Each longitudinal sound wave emitted has certain important characteristics, including wavelength, frequency, period and velocity. The distance between two consecutive and identical positions on the longitudinal wave is the wavelength, typically measured in meters and represented symbolically by lambda (λ). Frequency of the wave is the number of wavelengths or cycles that pass through a given point in one second, measured in Hertz (Hz) or cycles per second. Ultrasound frequency used in imaging is important for image resolution and the depth of penetration of the wave. The time taken for one particle in the medium through which the wave travels, to make one complete oscillation or cycle about its rest position is the period of the wave. The velocity of the longitudinal ultrasound wave is a measure of the density and compressibility of the medium through which it is propagating and is the speed of propagation of the wave. All acoustic waves are transmitted through the same medium at the same velocity even though their frequencies are different.

Individual movement of each longitudinal ultrasound wave can be described mathematically by the wave equation given by:

\[ \text{Velocity} = \text{Frequency} \times \text{Wavelength} \]

From this wave equation, since the velocity of ultrasound always remains constant for a particular medium, the product of frequency and wavelength of the wave is also a constant. In effect, if the velocity is kept constant, the wavelength of ultrasound in a medium is reduced as the frequency increases, which represents an inverse-square relationship.

If the same transducer probe, capable of producing sound waves of a particular frequency, is employed to scan an area of the body containing different tissue materials, the wavelength is longer in material with higher velocity. The higher the density of a material, the higher will also be the velocity of the sound wave. Generally, sound waves travel faster in media that are denser than air because of reduced compressibility. This clearly shows that density and compressibility of the material through which sound wave propagates have effects on the velocity of the wave. Acoustic impedance (Z) of the material through which sound wave traverses is a measure of the compressibility of the material.
Anatomy of the Ultrasound Beam
In practice, the ultrasound transducer probe behaves as though it were many individual small sources of sound, each of which contributes to the wave front exiting from it. This is due to superposition or summation of waves to form more complex waves of ultrasound beam. As the series of ultrasound waves that make up the beam travel parallel to each other, the beam is of comparable diameter to the transducer face. This segment of the beam is called the **near-field** or **Fresnel zone**. Beyond the near-field, the beam begins to diverge to form the **far-field** or **Fraunhofer zone**. Near-field and far field of the ultrasound beam are illustrated in Figure 1.3. The near-field and far field transition is the natural focal point or zone and is the point of greatest intensity and best lateral resolution for imaging. The divergence tendency of the ultrasound beam reduces the resolution or ability to distinguish two objects close together on the ultrasound image. It is possible to focus the ultrasound beam to cause convergence and narrowing of the beam for improvement of lateral resolution.

![Figure 1.3: Ultrasound waves in the beam from the transducer surface first remain parallel in the near zone ($Z_0$) and then diverge in the far zone.](image)

Interactions of Ultrasound Beam with Body Tissues
When ultrasound waves in the beam exiting from the transducer probe pass through human body tissues, the amplitude, intensity and velocity of the waves are reduced. This is the process of attenuation, which is defined as the rate at which the intensity of the ultrasound wave diminishes with the depth it covers or its penetration in the body tissue.
Tissue attenuation of ultrasound beam can be affected by many factors, including the frequency of the ultrasound waves constituting the beam. The higher the frequency of the beam, the higher the attenuation, and the less the penetration of the wave. The type of tissue through which the sound wave travels also affects attenuation, because some tissues absorb more than others. Attenuation is also affected by the depth to which the sound wave is expected to travels; the more distance the sound wave has to travel the more energy is lost.

Apart from the process of attenuation in the body tissues, the ultrasound waves can also undergo changes due to absorption, refraction, diffraction, interference, scattering, and reflection. Absorption is the only ultrasonic interactive process leading to heat production or removal of energy from the ultrasound beam. Refraction refers to change in direction of the ultrasound wave as it crosses a boundary because the ultrasound beam is not perpendicular to tissue interface. Generally, it does not produce severe problem in ultrasound imaging, but may be a source of artifacts due to false location or shape of objects. Ultrasound beam spreads out by the process of diffraction as it moves farther from the transducer or as it passes through a small opening. Interference with ultrasound waves causes them to be out of phase and affects uniformity of beam intensity. It is a useful consideration in transducer design.

Attenuation interaction by reflection is primarily responsible for all ultrasound images among other physical interactions stated above. When a sound wave is incident on an interface between two tissues, part of it is reflected back into the original medium. The amount of energy reflected back from a second medium depends on its ability to impede movement of ultrasound wave from the original medium. This inherent property of tissues is called impedance. The greater the difference in impedance between two tissues forming an interface, the greater is the amount of energy that is reflected back.

Reflection co-efficient (R) is the ratio of the intensity of the reflected wave to the incident wave. For example, R for interface between liver and kidney is only one percent. In some cases, the acoustic impedance can be so great that all the sound waves energy can be reflected, such as happens when sound comes in contact with bone or air. This is the reason why ultrasound is not used as a primary imaging modality for bone, digestive tract and lungs.
Ultrasound Resolution

In order to be of diagnostic quality, ultrasound images must be able to show quite distinctly structures within human body tissue. This ability of the ultrasound beam to distinguish or identify objects distinctly is known as resolution. This is of two main types, that is, spatial and temporal.

Spatial resolution is the ability of ultrasound to distinguish two separate objects that are close together in either the axial or lateral planes. Axial resolution concerns two objects along the axis of the ultrasound beam, while lateral resolution relates to objects located in the direction perpendicular to the ultrasound beam axis. Lateral resolution is generally poorer than axial resolution because unlike the latter, it is dependent on the width of the ultrasound beam. Two objects situated side by side cannot be distinguished if they are separated by a distance less than the width of the beam. Thus, lateral resolution is influenced by all the determinants of beam width, including the transducer frequency, focal zone of the ultrasound beam and gain. Temporal resolution, on the other hand, is the ability of the ultrasound beam to accurately locate structures or events at a particular instant in time. It is dependent on the frame rate and closely related to the Time Gain Compensation (TGC) process, which compensates for loss of echo amplitude with distance traveled by the ultrasound beam.

Strengths & Weaknesses of Ultrasound Imaging

Ultrasound beam from the transducer is capable of providing images of muscle, soft tissue and structure of organs very well and is particularly useful for showing the interfaces between solid and fluid-filled spaces. It renders "live" images, where the operator can dynamically select the most useful section for diagnosing and documenting changes, often enabling rapid diagnoses. Live images also allow for ultrasound-guided biopsies or injections. It has no known long-term side effects and rarely causes any discomfort to the patient. Ultrasound equipment is widely available and comparatively flexible with possible examination performance at the patient’s bedside.

Sonographic devices have trouble penetrating bone and perform very poorly when there is a gas between the transducer and the organ of interest, due to the extreme differences in acoustic impedance. Depth of penetration of ultrasound beam and image quality may also be limited by the human body size, especially in the obese patients. A high level of skill and experience is needed to acquire good-quality images and make accurate diagnoses. Thus, ultrasound imaging is highly operator-dependent.
Ultrasound Instrumentation
An ultrasound machine is typically a dedicated computer system, consisting of a central processing unit (CPU), display monitor, keyboard and transducer pulse controls. Optional parts of the ultrasound machine include disk storage devices and printers. The CPU processes the ultrasound data of interactions within the human body and displays the image in various modes depending on the type of ultrasound examination.

Operational mode of ultrasound may render static images in amplitude mode (A-mode) or brightness mode (B-mode). Ultrasound image may also be produced in dynamic modes, which include motion mode (M-mode) for dynamic evaluation of internal structures; real-time B-mode considered as the fluoroscopy of diagnostic ultrasound; and continuous or pulsed wave ultrasound for Doppler flow measurements and therapy.

The transducer pulse controls allow the sonologist to set and change the frequency and duration of the ultrasound pulses, as well as the scan mode of the machine. The commands from the sonologist are translated into changing electric currents that are applied to the piezoelectric crystals in the transducer probe for image generation and display. It is thus obvious from the foregoing that a basic knowledge of ultrasound physics and instrumentation is an essential ingredient of safe ultrasonography.
CHAPTER II

ULTRASOUND OF THE LIVER

Len Gordon Harris
Ahidjo A

INTRODUCTION

The Liver is the largest organ in the body, occupying most of the right hypochondrium, part of the epigastrium and left hypochondrium. It weighs about 1300 to 1600 grams in the adult with a volume of 1500 +/- 100cc in males and 1300 +/-100cc in females. Because of its frequent involvement in systemic and localised diseases, sonographic evaluation for focal and diffuse abnormality is frequently requested.

Sonographic Anatomy

The liver is divided into the right (Fig. 2.1) and left lobes (Fig. 2.2). The right liver lobe is separated from the left lobe by the main lobar fissure, which on longitudinal scan is seen as a echogenic line from the portal vein to the neck of the gallbladder. The caudate lobe which is situated on the posterior and superior surface of the left lobe, is small in size and bounded posteriorly by the IVC (Fig. 2.3), anteriorly by the fissure for the ligamentum venosum, the left hepatic lobe superiorly and the main portal vein inferiorly.

Figure 2.1: Normal right lobe of the liver. Note part of the right kidney displayed.
Figure 2.2: Normal sonographic anatomy of the left liver lobe (tongue like).

Figure 2.3: Normal right lobe of the liver showing the IVC and the hepatic veins.

Fig.2.4: Right lobe of the liver showing the tubular hepatic vein with no obvious wall.
There are ligaments and fissures used as landmarks in the sonographic evaluation of the liver which are echogenic (hyperechoic) in scanning. These are the Glisson capsule which covers the liver, the main lobar fissure, the falciform ligament, from the diaphragm to the umbilicus. The ligamentum teres (Round ligament) is seen as a rounded echogenic end of the falciform ligament.

It is important to understand the Vascular Anatomy of the Liver and the Couinaud’s Anatomy, which divides the liver into eight segments helps in doing so. The three hepatic veins, right, middle and left, which are thin walled (Fig. 2.4) and drain into the IVC divide the liver into four longitudinally. These are further subdivided transversely by a line through the left and right portal veins, thus creating the eight segments.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Caudate lobe</td>
</tr>
<tr>
<td>2</td>
<td>left superiolateral segment</td>
</tr>
<tr>
<td>3</td>
<td>left inferiolateral segment</td>
</tr>
<tr>
<td>4a/b</td>
<td>left lobe medial segments</td>
</tr>
<tr>
<td>5</td>
<td>right inferioanterior segment</td>
</tr>
<tr>
<td>6</td>
<td>right inferioposterior segment</td>
</tr>
<tr>
<td>7</td>
<td>right superioposterior segment</td>
</tr>
<tr>
<td>8</td>
<td>right anteriosuperior segment</td>
</tr>
</tbody>
</table>

These segmental divisions and subdivisions are important in planning surgery and in pinpointing the exact location of masses especially before treatment. Measurement for liver size is acceptable in the midclavicular line. A measurement less than 13cm is considered normal, whereas over 15cm is enlarged. Please note that there is a longue-like projection of the right liver lobe’s inferior lip known as the Reidel’s lobe.

The liver has a characteristic homogenous, fine echo pattern, slightly hyperechoic compared to the renal cortex and hypoechoic to the spleen. It is less echogenic than the pancreas. The hepatic veins and the reflective portal veins, the hepatic arteries and intrahepatic bile ducts lie with the homogenous parenchyma. The colour flow Doppler imaging shows the portal flow to be towards the liver (hepatopetal) and hepatic flow to be away from the liver (hepatofugal) towards the IVC.

The portal vein bright reflective appearance is due to the hepatic artery and the bile ducts running in the same direction and proximinity. The main portal vein formed by the splenic and superior mesenteric vein mostly divides as it enters the liver into the right and left portal veins. The hepatic veins right, middle and left enter into the IVC.
Relevant Physiology
The portal vein supply about 80% of the blood to the liver, the hepatic artery from the Coeliac Axis supply the other 20%. The hepatic veins; right, middle and left drain the blood from the liver into the IVC. The liver’s main functions include amongst others, metabolism, storage, digestion and detoxification.

Sonographic technique and evaluation
Adults should have nil by mouth for 6-8 hours or more. Children are best fasted over overnight and like babies and diabetic patients done first on the list the following day. A 3 -5 MHz transducer for adults and a 6-7.5 MHz for babies is recommended. It is advisable to adjust the overall gain, time gain compensation, focus and depth in order to get a very even grey-scale image front top to bottom.

The patient is scanned in the supine, left lateral decubitus and left posterior oblique positions in sagittal, transverse and oblique planes, both subcostally and intercostally. The following should be assessed.
- Liver size in the longitudinal plane
- Liver echogenicity/texture
- Any attenuation of the liver parenchyma
- The liver fissures, ligaments and vascular structures.
- Any space occupying lesions
- Any distortion or destruction of the liver architecture.

Liver pathology
Diffuse Diseases
1. Fatty infiltration: Fatty infiltration of the liver is due to the hepatocytes having increased lipids within. Causes of this include diabetes mellitus, alcohol abuse, steroids, obesity, starvation, severe hepatitis, pregnancy, chronic illness e.g. ulcerative colitis. In most cases it is reversible after treatment.

Sonographic findings:
- Increased echogenicity of the liver appearing as a bright liver
- Enlargement of the liver or the affected lobe
- Difficulty in visualizing the portal veins and hepatic veins due to increased attenuation of the ultrasound waves.

Figure of Fatty liver and another of focal sparing
Ultrasound is very sensitive in the detection of Fatty liver. The sensitivity is about 86% in mild cases this is Grade 1 up to 100% in grade 3 in the Sonographic classification of fatty liver. In Acute fatty liver in Pregnancy (AFLP) the ultrasound appearance may be normal. Other characteristics of fatty liver include focal sparing and patchy distribution of fat especially in the right liver lobe.

2. **Hepatitis.** Hepatitis can be acute or chronic and is a general term used for infectious and or inflammatory disease of the liver. It can be due to viral infection, from chemical and drugs reactions/toxicity. Alcohol and autoimmune disorders.

   a. **Acute Hepatitis.** The result of infection from viruses. The different types are Hepatitis A, B, C, D, and E. In the West African subregion Hepatitis B is prevalent. It is transmitted by blood, saliva, semen/sexual contacts and can progress to chronic hepatitis and the risk of developing Hepato cellular Carcinoma.

   **Sonographic Findings:**
   - The liver may appear normal
   - Portal vein borders may appear more prominent than usual
   - The liver may appear slightly echopenic compared to the portal vessel wall reflectivity or slightly echogenic.
   - There is thickening of the Gallbladder wall above 3mm.
   - Hepatomegaly and splenomegaly may be present.

   b. **Chronic Hepatitis.** This is defined as existence of clinical and or biochemical evidence of inflammation of the liver for more than 3-6 months. There are three types.

   - Chronic active or aggressive hepatitis (CAH)
   - Chronic persistent Hepatitis (CPH)
   - Chronic lobular Hepatitis

   CPH is a benign self-limiting type whilst CAH shows continuing liver cells necrosis and may lead to cirrhosis and or liver failure. In CLH there is inflammation of the portal tracts and parenchyma.
Sonographic findings:
- Coarse liver parenchyma with altered echo pattern
- No liver size increase
- Decreased prominence of the portal triad (Compare Acute Hepatitis)
- There may be some degree of distal attenuation depending on the amount of fatty infiltration. Necrosis and fibrosis present.

3. Cirrhosis: Cirrhosis is the end result of several conditions such as hepatitis, long term alcohol abuse, carcinogens and other types of infections. It is a chronic disease in which the lobes are covered with fibrous tissue and there is degeneration, necrosis and regeneration of the liver parenchyma. Metabolism start to fail and his causes clinical signs. Cirrhosis may lead to liver failure and portal hypertension and ascites. There are micronodular (less than 3mm) and macronodular more than 3mm) types. Other classifications are biliary, fatty etc.

Sonographic Findings:
- The liver size may be normal to start with but tends to shrink in size as the condition progresses.
- The caudate lobe and the left lateral lobes are usually spared of the shrinkage and may even be larger than normal thus giving a lobe to right liver lobe ratio of more than 0.65 on a transverse scan just below the portal vein bifurcation.
- Coarse pattern ad as result of fibrosis and nodularity.
- Increase in attenuation may be present as well as decrease in vascular markings

4. Congestive Heart Failure: There is passive liver congestion as a result of heart failure

Sonographic Findings:
- There is hepatomegaly with dilated hepatic veins and the IVC

5. Glycogen Storage Disease: There are about six types of Glycogen Storage disease. Handling these in detail is beyond the scope of this book. The most common type 1 (V.Gierke’s) in which large quantity of Glycogen is stored in the liver and kidneys show following sonographic findings.
Sonographic Findings:
- Hepatomegaly
- Hyerechogenicity due to the increased echo pattern
- Moderately increased attenuation. Usually associated with FNH and Adenomas.

Focal liver Lesions.
The focal lesions of the liver may be single (Fig. 2.5) or multiple, benign or malignant and very few hepatic lesions have specific sonographic appearances. Focal lesions of the liver may be cysts, abscesses, tumors, metastasis, haematoma (Fig. 2.6). It is at times difficult to differentiate whether the mass is in the liver or not that is hepatic or renal. Intrahepatic lesions may cause displacement of vascular structures or bulging of the capsule or IVs depending on its position. A mass outside the liver on the other hand may invaginate liver capsule, form a triangular fat wedge or renal displacement.

Figure 2.5: A rounded focal echogenic mass lesion involving the right lobe of the liver with peri-lesional hypoechogenicity.
General ultrasonic Appearances

- Hyperechoic: The lesion is more echogenic than the surrounding e.g. Haemangiomas
- Hypoechoic: Less echogenic than the surrounding e.g. Small HCC
- Cystic Lesions: Have few or no internal echoes with posterior enhancement
- Target lesion/ bull’s eye: Hyper or Iso echoic with a hypoechoic halo or rim around it. Thick rims (3-5mm) metastasis thin ones (1-2mm) HCC

Figure 2.6: Sagittal ultrasound scan of the liver showing a huge mixed echogenic mass with sonolucent areas due to necrosis in the right lobe. A histologic diagnosis of hepatoma was made.

Cystic Lesions
Cysts are more often than not congenital as a result of developmental failure of the biliary duct, but can also be the result of trauma or abscess. They can be classified as simple /congenital cysts, traumatic, parasitic, inflammatory, pseudocysts or polycystic disease. The walls may calcify.

Simple hepatic cysts
They are mostly incidental, do not cause pain and the patients normally do not have symptoms. Larger ones may cause pain and or mass effect or may bleed within and cause pain. They occur more in women than men and more in the middle-aged or elderly.
Sonographic Findings:
- They are smooth with thin walls
- Well defined back wall and borders
- Anechoic with posterior acoustic enhancement
- May contain one or more thin fine internal septa.
- May have calcified wall

Polycystic Liver Disease
- Polycystic liver disease is an autosomal dominant disease.
- 60% of patients have associated polycystic renal disease
- 40% of patients with polycystic renal disease have liver cysts.

Ultrasound Findings:
- The cysts are of different sizes and at random within the liver
- They are usually small, less than 2-3 cm and multiple in the liver
- Anechoic, well defined borders with posterior acoustic enhancement
- May cause hepatomegaly is numerous
- Those at the porta hepatis when large may cause biliary obstruction.

The differential diagnosis includes echinococcus, hematomas, necrotic metastasis.

Infective/Inflammatory Lesions
Abscesses occur from spread of infection through the biliary tree, portal veins, hepatic artery, trauma or surgery. They may be intrahepatic, subhepatic or subphrenic. Lesions from the rare Armillifer armillatus may also be identified on ultrasound (Fig. 2.7).
**Pyogenic abscess**

Pyogenic abscess arise from complications of cholangitis, colitis, appendicitis, diverticulitis, abdominal surgery, trauma.

*Ultrasound appearances:*

The appearances depend on the time frame of the abscess.

**Early**:
- In the first few days that is early- they appear as diffuse, ill-defined, hypoechoic areas.
- They size varies from about 1 cm to larger
- The right lobe is the commoner site

**Late** -
- The abscess becomes better defined, still hypoechoic
- The Shape may be round, oval or irregular with acoustic enhancement
- It may be complex , with a mixed echo pattern from necrosis, some debris and Gas formation
- When gas and calcifications are present, hyperechoic areas with posterior acoustic shadowing are seen

**Amoebic Abscess**

This entity is caused by the protozoan parasite *Entamoeba Histolytica*. The spread is from contaminated water and food ingestion. The disease is primarily of the colon but can spread to the liver, lungs and brain. The organisms reach the liver via the portal vein through the mucosa of the colon.
Ultrasound Findings:

- It can appear similar to pyogenic abscess, mostly in the right lobe
- The ultrasound appearance is variable and not specific
- The shape may be round or oval with no significant wall echo
- Hypoechoic compared to the surrounding liver parenchyma
- Homogeneous low-levels internal echoes
- Posterior acoustic enhancement may be seen

Echinococcal cyst (Hydatid Cyst)
This is a parasitic infection found especially in sheep and cattle grazing areas. The parasite (a worm) is passed on to humans (as the intermediate hosts) through infected dogs. When the worms get to the small intestine in humans, the larvae go through the mucosa and are conveyed to the portal circulation into the liver. The hydatid cyst has two layers. Smaller daughter cysts may develop from the inner layer.

Figure 2.8: A confirmed case of hydatid liver disease showing a predominantly cystic mass with solid components.

Ultrasound findings:
- The Ultrasound pattern of hydatid Cysts (Fig. 2.8) varies from a simple cyst to a complex mass

Sickle Cell Anaemia
Sickle cell anemia causes abnormalities in the abdomen relating to haemolytic anaemia in liver, gallbladder, spleen and the kidneys.
Ultrasonographic Findings

**Liver:** Hepatic complications are attributed to vascular occlusion as a consequence of haemolysis. Sonographically the liver appears enlarged and hypechoic. A rare manifestation is the occurrence of hepatic abscess which appears a well defined hypo/anechoic lesion with strands within it. It may be single or multiple.
REFERENCE
CHAPTER III
ULTRASOUND OF THE GALLBLADDER
Ahidjo A

INTRODUCTION
The gallbladder is a blind-ended sac, an outpouching from the biliary system and it stores bile. Prior to a meal, the gallbladder may be full of bile but empties its contents after meals into the small intestine and becomes flat. Bile is important for fat digestion. It lies immediately beneath the inferior surface of the liver in which it produces a smooth indentation. The inferior relations of the gall bladder are the second part of the duodenum and hepatic flexure of the colon. It is around 10 cm long and connected to the common hepatic duct by the cystic duct. The confluence of these gives rise to the common bile duct. It has the fundus, body and the neck. The fundus of the gall bladder lies close to the anterior abdominal wall. Variations exist for much of the gall bladder anatomy, including variation in the relationship of the cystic duct to the hepatic artery, the length and insertion of the cystic duct, the origin of the cystic artery.

The gall bladder is most commonly evaluated with ultrasound, and gall stones or inflammatory thickening are easily appreciated. It is usually covered on its inferior surface with peritoneum although this may surround it completely.

Sonographic Technique
- Use a 5 MHz or higher transducer
- 8-12 hour fasting state
- Patient position:
  - Supine or left posterior oblique and one other position (lateral decubitus or erect)
Sonographic anatomy

- The gallbladder is an excellent organ to image by sonography, because it is a fluid-filled structure with no internal echoes.

- It is visualized as an anechoic pear-shaped structure outlined by a smooth thin wall (Fig. 3.1 and Fig. 3.2).

- Any abnormality within the gallbladder becomes outlined by the bile and is easily seen.

Figure 3.1: Long axis of a normal gallbladder

Figure 3.2: Transverse axis of a normal gallbladder.

NON-DISTENDED GALLBLADDER

- A post-prandial gallbladder cannot be differentiated from an abnormal diseased, contracted gallbladder.

- An empty gallbladder is difficult to scan and results are unreliable. The gallbladder should always be examined in the fasting state, when it is maximally distended.
Inadequate Fast

- An inadequate fast may result in slight gallbladder wall contraction and mild wall thickening (Fig. 3.3), which in turn may lead to incorrect diagnosis.

![Figure 3.3: Long axis of an undistended gallbladder. Note the portal vein below it with echogenic wall.](image)

Gallbladder septation

- Rarely gallbladders contain true septations.
- These are congenital in origin and are of no clinical significance.
- A gallbladder folded back upon itself may simulate septation.

Phrygian cap

When the fundus of the gallbladder folds over on itself, it creates the appearance of a cap, called the “phrygian cap” (arrow).

Gallstones

- Incidence: 10-20% of population
- Various symptoms
- Females > males
- Obesity
- Pregnancy
SONOGRAPHIC CRITERIA (Fig. 3.4)

1. Echogenic focus
2. Acoustical shadow
3. Mobility

Figure 3.4: An echogenic foci within the gallbladder casting posterior acoustic shadowing in keeping with a gallbladder stone.

As gallstones rub against each other, over time they may acquire flat surfaces. These are called faceted stones, because they are like the cut surfaces on gemstones.

In order to avoid errors, you must:
- image a gallstone, as any structure, in two perpendicular planes
- demonstrate mobility of the stone
- demonstrate shadowing
- check the cystic duct carefully

All gallstones (>1mm), regardless of chemical composition, shadow.

This requires optimization of technique, which is not always possible in vivo.

Differential Diagnosis of non-visualization of gallbladder
- Cholecystectomy
- Chronic cholecystitis ± stones
- Gallbladder carcinoma
- Obstruction of biliary tree proximal to cystic duct
- Congenital absence of GB
**NON-SHADOWING ECHOGENIC FOCI IN GB**
- Tiny calculi
- Polyps
- Sludge balls
- Cholesterol crystals
- Blood clots
- Pus
- Carcinoma
- Metastases
- Parasites

**GALLBLADDER POLYPS**
- Polyps are echogenic round masses attached to the gallbladder wall. They are distinguished from small calculi, because they do not move with position change and do not cast acoustical shadows.

**SLUDGE**
- Sludge signifies poor emptying of the gallbladder, whether it be due to obstruction, prolonged fasting or hyperalimentation. This is common among ill patients, who are fed intravenously. As soon as the patient is able to eat, the gallbladder contracts and the sludge is expelled.

**GALLBLADDER WALL THICKENING**
- Normal thickness 1-2 mm
- Abnormal >3mm
- Must be fasting (distended GB)
- May be diffuse or focal thickening
- May have striations (layers)
- Diffuse wall thickening is non-specific
CAUSES OF DIFFUSE GB WALL THICKENING

- Non-fasting
- Cholecystitis - acute or chronic
- Ascites - edema, hypoalbuminemia, artifact
- Liver disease - hepatitis, cirrhosis
- Renal disease - failure, uremia
- Pancreatitis
- CHF
- Tumor infiltration
- Adenomyomatosis
- AIDS cholangiopathy
- Sepsis

ACUTE CHOLECYSTITIS

_Ultrasound findings_ (Fig. 3.5):

- Pain directly over gallbladder (sonographic Murphy’s sign)
- Gallstones:
  - only 1/3 get acute cholecystitis
  - Shadowing calculi are located within the gallbladder.
- Thickened gallbladder wall
- Enlarged gallbladder
- Pericholecystic fluid
- Striated wall
- Intraluminal membranes
- Color Doppler: flow, nonspecific
- Layers of edema form concentric rings of alternating dark and white bands around the gallbladder in this case of acute cholecystitis
Figure 3.5: Acute cholecystitis showing thickened gallbladder wall with periluminal hypoechogenicity due to inflammatory exudates.

Complications
- Gangrenous cholecystitis
- Hemorrhagic cholecystitis
- Perforation/abscess
- Emphysematous cholecystitis

Gangrenous cholecystitis
- Gas-forming bacteria
- Ulceration & sloughing of mucosa
- Necrosis
- Hemorrhage
- Microabscesses
- Intramural gas
- Intraluminal gas

Ultrasound findings:
- Striated wall thickening
- Intraluminal membranes
- Mass-like protrusions into gallbladder
- Larger pericholecystic collections
- Internal echoes due to pus
Acalcholous cholecystitis

- Signs of acute cholecystitis (except gallstones)

- Clinical setting
  - major surgery -parenteral nutrition
  - severe trauma -underlying illness
  - severe burns -sepsis

- Multifactorial etiology
  - ischemia -chemical toxicity
  - infection -obstructed duct

GALLBLADDER CARCINOMA

- Elderly patients, poor prognosis

- Chronic irritation from longstanding gallstones and chronic cholecystitis

- Polypoid mass, irregular outline

- Invasive through wall and into surrounding tissues

- Carcinoma of the gallbladder is the most common primary biliary carcinoma and the most common malignancy of the gallbladder, sarcoma being extremely rare.

- GB carcinoma is usually seen in elderly females and is usually associated with gallstones.

- The longstanding presence of gallstones and chronic GB irritation supposedly lead to the malignancy.

- An irregular solid gallbladder mass usually in the presence of gallstones, as shown here, is the typical characteristic finding on sonography.

- Sometimes the carcinoma presents as focal or generalized wall thickening, which is difficult to differentiate from inflammatory conditions.

*Doppler findings in gallbladder carcinoma*

- Demonstration of blood flow, especially arterial, within a solid gallbladder mass is suggestive of a carcinoma, as in the three cases shown in the slide.

- Since color Doppler is not totally reliable due to occasional artifacts, one should confirm flow with pulsed Doppler.
GALLBLADDER METASTASES

- Rare
- Late manifestation of disease
- Other metastases are usually present
- Primary tumors:
  - Melanoma
  - Breast
  - GI
  - Lung
- Metastases to the gallbladder are rare. Of these the most common primary tumors are melanoma, breast and colon carcinoma.
- Metastases to the gallbladder are usually a late manifestation of the disease and the patients have other known metastases.

Sickle Cell Anaemia
Sickle cell anemia causes abnormalities in the abdomen relating to haemolytic anaemia in liver, gallbladder, spleen and the kidneys.

Ultrasonographic Findings

**Gallbladder:** The most important manifestation is the occurrence of gallstone. Others include Wall thickening, presence of biliary sludge, cholesterol polyp. In acute cholecystitis, a circumferential lucent zone may be seen suggestive of gallbladder wall oedema. In chronic cholecystitis, fibrosis leads to high level echoes and the gallbladder is usually small.

**Splenic:** The usually appears small in size and density calcified. Splenomegaly may occur and is suspected in children when the spleen is more than 1.25 time longer than the adjacent normal kidney. Splenic infarcts appear as wedge-shaped rounded hypoechoic areas. Other findings include multiple punctuate echogenic foci in the spleen, hyperechoic focal parenchymal lesion may also be seen.

**Renal:** Renal enlargement is seen with medullary or diffuse increase in reflectivity (increase in medullary echogenicity). Other manifestation include renal papillary necrosis as well as multiple rounded or triangular cystic spaces communicating with the collecting system in the modularly region without a dilated renal pelvis.
CHAPTER IV

ULTRASOUND OF THE SPLEEN
Ahidjo A

INTRODUCTION

The spleen is the largest lymphoid organ of the reticuloendothelial system. The reticuloendothelial system is involved in:

- immediate body defense against microorganisms
- establishment of specific immune response
- haematopoiesis in the fetal life
- red cell breakdown and bile pigment metabolism

The spleen is a crescentic shaped organ located in the left upper quadrant of the abdomen. The spleen is the size of a fist, measuring up to 12cm long, 7cm wide and 3-4cm thick. Its long axis is in the line of the tenth rib and its lower pole does not usually extend beyond the midaxillary line. It is protected by the ribs and surrounded by numerous air-filled structures, namely the left lung, stomach, splenic flexure and small bowel loops. The spleen is smaller than the liver and does not fill out the left quadrant compared to the liver on the right. These two factors make scanning of the spleen more difficult than the liver.

Blood supply of the spleen is from the splenic artery arises from the coeliac trunk. The splenic vein receives the inferior mesenteric vein and joins with the superior mesenteric vein to form the portal vein.

Of the various imaging modalities available, including scintigraphy, CT and MRI, ultrasound provides an economic, non-invasive modality for display of both focal and diffuse pathologic condition of the spleen. Many of these appearances are not specific, but a correct diagnosis is usually possible when the ultrasound appearances are interpreted in the light of the clinical condition.
SONOGRAPHIC TECHNIQUE

- The spleen is scanned from the left flank, in the coronal plane with the patient supine (Fig. 4.1).
- The patient may be scanned in prone or in the right decubitus position.
- The left arm is extended above the head in the right decubitus position to open up the intercostal spaces.
- The intercostal spaces may be widened by putting a pillow under the patient’s right side.
- A 3.5 - 5.0MHZ frequency transducer may be required for optimal penetration and resolution.
- Apply gel and examine the spleen obliquely or longitudinally in coronal plane in the 10th or 11th intercostal space.

**Note:** If this approach is suboptimal, subcostal scans may be taken after the patient is placed in the right posterior oblique or right lateral decubitus position. This is used as a secondary approach, because in this position the spleen tends to fall away from the ribs and bowel gas or lung air interpose between the ribs and the spleen. The spleen must be examined in two orthogonal planes.

![Figure 4.1 Coronal view of the normal spleen.](image)

**SONOGRAPHIC ANATOMY**

- The spleen lies in the left hypochondrium under the diaphragm (bright curvilinear echogenic structure).
- Posteriorly the diaphragm, left pleura, left lung and the ribs are in contact with the spleen.
- The visceral surface of the spleen is in contact with the left kidney and the splenic flexure.
- The tail of the pancreas crosses the hilum of the left kidney to reach the hilum of the spleen.
- The stomach is related to the spleen anterior-medially.
Normal texture and echopattern
Homogeneous low–level echo pattern:
- Similar or slightly higher than the liver
- Normal splenic parenchyma is more echogenic than the renal parenchyma

Ultrasound splenic size
Measured along its long axis (normal = 8-12cm)

Splenic vessels
- Vessels in the hilum of the spleen are identifiable
- The splenic artery runs along the superior or posterior border of the pancreas before entering the hilum of the spleen
- The splenic artery is accompanied by the splenic vein
- The left coronal plane is the best approach for evaluation of the splenic vessels by Doppler, because the angle is optimal for evaluation of direction of blood flow. On this color Doppler scan the splenic artery is colored red, signifying flow toward the transducer, while the vein is colored blue, because the flow is away from the transducer

SPLENIC DISEASES
Congenital disorders
- Aplasia: Absence of the spleen, a rare disorder associated with other congenital anomalies, e.g. cardiac
- Hypoplasia: more common
- Accessory spleen
  - common disorder
  - comprises 20-30% of postmortem examinations
  - Near splenic hilum or vessels
  - Usually solitary, may be multiple
  - may simulate tumour on ultrasound
  - Small, smooth, round or ovoid mass
  - Isoechoic with splenic tissue
  - “Born again spleen” - hypertrophy of accessory spleen after splenectomy
- Anomaly of position -Wandering spleen
  - may be congenital or occur during pregnancy
  - homogeneous mass on ultrasound
  - may be found in pelvis or any position in the abdomen
SPLENOMEGALY
   - Definition: greater than 13 cm in longest length
   - Additional: greater than 6 cm in thickness
   - Splenomegaly is often suspected when one is unable to measure the entire length of the spleen on one image. For confirmation of a visual impression, the length of the spleen should be measured.
   - Splenomegaly is often detected visually when the spleen appears longer and larger than the left kidney.

CAUSES OF SPLENOMEGALY
   - Infection (malaria, hepatitis)
   - Heart failure
   - Tumor (leukemia, lymphoma, metastatic, primary tumors)
   - Portal hypertension
   - Blood dyscrasias (sickle cell disease, hemolytic anemias)
   - Other infiltrative disorders

SPLENIC CYSTS
Classification:
   1. Non-parasitic
      - Primary (true)
        - Congenital (Fig. 4.2)
        - Neoplastic
        - Dermoid
        - Epidermoid
        - Lymphangiomasis
      - Secondary
        - Pseudocyst
   2. Parasitic
      - Hydatid (Echinococcus) is the most common (Fig. 4.3)
   3. Post-traumatic cyst
Note:

- Primary or secondary splenic cyst are indistinguishable by ultrasound.
- Primary cysts, or true cysts, have an epithelial lining and are rare.
- Secondary, or false cysts are:
  - more common
  - usually due to previous old trauma
  - due to hematoma

Figure 4.2: A simple splenic cyst. Note the distal or through posterior enhancement.

Figure 4.3: Cystic masses within the spleen. The larger shows thick irregular wall with an incomplete septa.
Ultrasound features:

- Ultrasound allows immediate assessment of intra-splenic cyst
- Splenic cysts usually meet criteria of a simple cyst, but they may be:
  - slightly irregular in their outline
  - complex, containing echoes due to hemorrhage, infection, debris or crystals
  - Some of the cyst walls may calcify.
- Simple cysts are: spherical or ovoid shape, anechoic, thin walled and posterior enhancement.
- Parasitic cysts in the spleen are usually due to echinococcal disease, which is seen in endemic areas. A unilocular simple cyst is the most common presentation of an echinococcal cyst in the spleen and is indistinguishable from other etiologies of a cyst. Parasitic cyst appear as anechoic lesions with possible daughter cyst, wall calcification, internal septations, solid masses with fine internal echoes and poor distal enhancement
- Non-parasitic true cyst appear on ultrasound as hypoechoic or anechoic foci with well-defined wall and increased through transmission
- Haemorrhage within a cyst may produce a fluid level

**SPLENIC TRAUMA**

Splenic trauma manifest as:

- Contusion or laceration with or without capsular disruption
- Avulsion of the vessels at the splenic hilum.
- After undergoing organization, an intrasplenic hematoma becomes a post-traumatic pseudocyst.

Intrasplenic, subcapsular or perisplenic hematomas have sonographic features identical to hematomas elsewhere in the body. These fluid collections demonstrate the typical temporal changes of blood, starting initially as echogenic fluid, subsequently developing irregular echoes from lysis of clot and fibrin deposition, and eventually becoming anechoic.

**SPLENIC ABSCESS**

They usually result from bacterial endocarditis or septicemia and may follow spread from adjacent organs. They are more common among immunocompromised patients.

- On ultrasound, splenic abscesses have typical appearances of abscesses elsewhere in the body,
that is:
- Complex
- Predominantly cystic masses
- Thick, irregular walls
- Inhomogeneous internal echoes from debris
- Septation
- May contain a fluid-fluid level
- Good sound transmission
- Sometimes they contain gas

They may also be echogenic, in which case they may be indistinguishable from the splenic parenchyma or may appear solid.

**Note:** Sonographically abscesses are indistinguishable from hematomas or necrotic tumors.

**SOLID SPLENIC MASSES**
- Granulomas
- Infarct
- Hemangioma
- Hamartoma
- Lymphoma
- Metastases
- Angiosarcoma

**SPLENIC INFARCT**
Infarcts are one of the most common focal lesions in the spleen. Infarction of the spleen may be due to:
- Septic emboli
- Subacute bacterial endocarditis and atrial fibrillation
- Thrombosis of the splenic vessels, commonly seen in sickle cell disease, but also in pancreatitis, sarcoidosis, leukemia, lymphoma and polyarteritis nodosa.
The typical appearance is that of:
- A triangular or wedge-shaped hypoechoic defect with its base toward the periphery of the spleen.
- With time the defect may acquire some increase in echogenicity and may become hyperechoic

**SPLENIC HEMANGIOMAS**
The most common appearance is one or more well-circumscribed, sharply marginated, homogeneous, hyperechoic rounded masses.

**LYMPHOMA IN THE SPLEEN**
When lymphoma involves the spleen with focal masses, they are usually multiple and hypoechoic, some having a target-like appearance with echogenic centers. Splenic Hilar adenopathy may also be seen with lymphoma in the spleen. Lymphoma in the spleen may also present as a single or multiple hyperechoic masses.

**SPLENIC METASTASES**
Metastases to the spleen may be cystic, because the primary tumor is cystic or solid. Similar to other metastases, splenic metastases may develop complications of cystic degeneration, hemorrhage, necrosis, or infection.

Metastases to the spleen are rarely seen outside of autopsy. They are usually a late manifestation of widespread disease from hematogeneous spread of tumor. Solitary metastases, are usually multiple masses with a variety of sonographic appearances which include:
- Hypoechoic,
- Hyperechoic,
- Homogenous, and heterogeneous masses,
- With and without cystic changes.

**Sickle Cell Anaemia**
Sickle cell anemia causes abnormalities in the abdomen relating to haemolytic anaemia in liver, gallbladder, spleen and the kidneys.

**Splenic**: The usually appears small in size and density calcified. Splenomegaly may occur and is suspected in children when the spleen is more than 1.25 time longer than the adjacent normal kidney. Splenic infarcts appear as wedge - shaped rounded hypoechoic areas. Other findings include multiple punctuate echogenic foci in the spleen, hyperechoic focal parenchymal lesion may also be seen.
CHAPTER V

ULTRASOUND OF THE PANCREAS

AHIDJO A

INTRODUCTION
The pancreas is retroperitoneal organ with the exception of the tail, which lies in the splenorenal ligament. It develops from a large dorsal bud in the duodenum and a smaller ventral outpouching from the side of the common bile duct. The ventral outpouch rotates posteriorly to unite with the lower part of the dorsal bud enclosing the superior mesenteric artery and vein between them.

The pancreas is averagely 15 cm long. It lies transversely and slightly oblique, with the head lower than the tail. The pancreas is divided into head, neck, body and tail. It has two ducts; the main pancreatic duct of Wirsaw and an accessory duct of Santorini. The main duct receives smaller ducts along its length and finally joins the common bile duct to enter the duodenum at the ampulla of Vater.

Blood is supplied from the splenic and pancreatico-duodenal arteries. The corresponding veins drain into the portal system.

Sonographic Technique

- For trans-abdominal approach position the patient supine
- Uncover the dress in the region of the upper abdomen
- Use 3-5MHZ transducer
- Apply gel and place the transducer transversely at the level of L2 vertebrae below the sub-costal margin
- Move the transducer up or down to obtain the “comma shaped” pancreas
- Adjust the transducer to show the long axis of the pancreas
- Adjust to obtain the typical “dove-shaped” image of the celiac axis and use the hepatic and splenic arteries as landmarks
- Visualization is improved by filling the stomach with water, deep breath and the use of contrast agents
Sonographic Anatomy
- Located in the anterior para-renal space
- The pancreas is “Comma-shaped”
- Head in the concavity of the second part of the duodenum
- CBD can be seen as two bright lines at the head of the pancreas
- Gastro-duodenal artery is located at the head-neck margin as two bright lines
- Pancreatic duct can be seen as two broken white lines along the long axis of the pancreas
- Pancreas has a homogeneous mid-level echo pattern (Fig. 5.1); slightly brighter than the liver parenchyma
- Pancreas lies at the level of L2/L3 region
- The head, neck, body and tail are visualized distinctly
- Head measures approximately 3.0cm in size
- Body measures approximately 2.5cm in size
- Tail measures approximately 2.0cm in size
- Pancreatic duct measures approximately 2mm in diameter

Figure 5.1: A transverse ultrasound scan through the pancreas. Note the hypoechoic head (asteric)

RELATIONS
- Superioly are the first part of the duodenum, left lobe of the liver and the gastroduodenal artery
- To the right of the midline are the second part of the duodenum, porta-hepatic region and the CBD (<6mm)
- Inferioly are the splenic vein, SMV, SMA, IVC and the aorta
- To the left of the midline are the stomach and the left kidney
CONGENITAL ANORMALIES

1. **Ectopic pancreas:**
   - most common pancreatic anomaly
   - frequent sites are the stomach, duodenum, small bowel, and large bowel
   - seen on ultrasound as small (0.5-2.0 cm) polypoid masses of similar echopattern to pancreas
   - acute pancreatitis or tumor may occur in them

2. **Annular pancreas:**
   - rare
   - more common in males than in females
   - On ultrasound, head of the pancreas surrounds the second part of the duodenum
   - may be mistaken for a mass
   - other modalities like CT, ERCP or MRI may be more appropriate for diagnosis

3. **Pancreas divisum:**
   - occur due to absence of fusion between the dorsal and the ventral portions of pancreas
   - both portions are drained by separate ducts that do not communicate
   - hypertrophy of the uncinate process is seen
   - the SMV tunnels through the center of the pancreatic divisum

4. **Fibrocystic disease:**
   - hereditary disorder of exocrine glands
   - occur in children and young adults
   - normal size pancreas
   - small cysts may be present
   - acini and ducts are dilated
   - dilated ducts may contain calculi
5. **Congenital cysts:**
   - results from anomalous development of the pancreatic ducts
   - multiple cysts between 3-5cm are seen

**ACUTE PANCREATITIS**

Causes:

- Alcohol
- Trauma
- Gallstones
- Congenital hyperlipidaemia
- Abdominal infection
- Inflammation from adjacent peptic ulcer
- Vascular thrombosis and embolism
- Drugs

Complications:

- Pancreatic pseudocyst
- Pancreatic ascites from rupture of pseudocyst
- Pancreatic abscess
- Pancreatic necrosis
- Duodenal and CBD obstruction
- Venous thrombosis
- pseudo-aneurism

*Laboratory finding:*

- increased serum amylase level (non-specific)
Ultrasound findings:

- Focal tenderness - normal appearance on ultrasound
- Textural changes - decrease echogenicity
- Enlargement.
  - focal (in focal acute pancreatitis) or diffuse
  - more than 3cm for head and tail
  - rounding of the borders
  - massive enlargement in phlegmonous or haemorrhagic pancreatitis
- Anterior compression of the IVC by the enlarged head of the pancreas
- Dilated pancreatic duct
- Fluid collection may be:
  - Peripancreatic
  - Periduodenal
  - Anterior pararenal

HAEMORRHAGIC PANCREATITIS:

- Rapid progression of acute pancreatitis
- There is diffuse enzymatic destruction of the pancreatic tissues
- Specific ultrasound finding depend on the age of the haemorrhage
- A well-defined homogeneous mass in the area of the pancreas
- Grey Turners sign - hemorrhagic areas in the flanks
- At one week the mass may appear cystic with solid elements or septation

PHLEGGMONOUS PANCREATITIS

- Phlegmon is a spreading area of diffuse inflammation
- Commonly involves the lesser sac, left anterior pararenal space and transverse mesocolon
- Appears hypoechoic with good through transmission
CHRONIC PANCREATITIS

Patient present with more persistent but less severe pain. Occurs following repeated episodes of acute pancreatitis and alcoholism. Pathologically the pancreas shows increased fibrosis and chronic fibrotic changes.

*Ultrasound features:*

- Irregular pancreatic outline
- Dilatation of the pancreatic duct
- Calculi- echogenic with acoustic shadowing
- Focal enlargement
- Generalized decrease in size
- Increased echogenicity due to fibrosis

ACUTE ON CHRONIC Pancreatitis

- May show features of both acute and chronic pancreatitis

PANCREATIC PSEUDOCYST

The wall is not true cyst wall, hence the name pseudo (false)cyst. Acquired true cyst are retention cysts, parasitic cysts or neoplastic cysts.

Causes:

- Trauma
- Acute pancreatitis (11-18% of patients with AP)
- Chronic pancreatitis
- Sites:
  - Lesser sac is the most common location
  - Other sites are the anterior pararenal space, liver, spleen, mediastinum, and the mesentery
Value of ultrasound:

- Detection of pseudocyst
- Serial follow-up of the evolution of a collection
- Diagnostic aspiration or therapeutic percutaneous drainage

Ultrasound appearance:

- Anechoic mass with distal enhancement
- May have internal echoes, fluid-fluid levels or irregular borders especially in hemorrhagic or infective conditions
- May be multiple or septated

Note: Spontaneous rupture may occur.

PANCREATIC TUMOURS
ADENOCARCINOMA

- Most common primary tumour of the pancreas
- Occur in the elderly
- The head is the most frequent site (60-70%), followed by the body (20-30%) and tail (5-10%)
- Presents with weight loss, chronic severe abdominal or epigastric pain, painless jaundice
- The presence of dilated gallbladder and a palpable mass is strongly suggestive of carcinoma (Courvoisiers law)
- Metastasis to the biliary tree, lymph nodes and liver

Value of ultrasound:

1. Detection of tumor mass
2. Measurement of size of the mass
3. Establishment of the extent of local and metastatic spread
4. Mapping of tumor port sites for radiotherapist
5. Guidance for percutaneous biopsy
Ultrasound findings:
- Loss of normal pancreatic parenchymal pattern
- Hypoechoic mass is more common
- Irregular borders
- CBD or pancreatic duct enlargement
- Displacement of SMV posteriorly by the pancreatic mass
- Compression of the IVC
- Portal or splenic vein displacement and thrombosis
- Metastasis are seen in the liver, para-aortic nodes or portal vein

CYSTADENOMAS
- Rare
- May be benign or malignant
- Arises from the ducts as a cystic neoplasm
- Large cyst with or without septation
- Pancreatic pseudocyst is a differential

Ultrasound findings:
- Anechoic mass with posterior enhancement and irregular margins
- Anechoic mass with homogeneous internal echoes
- Anechoic mass with irregular internal vegetations
- Completely echogenic mass with non-homogeneous pattern
ISLET CELL TUMOUR
- May be benign adenomas or malignant tumors
- May be functional (60% insulinomas and 18% gastrinomas) or non-functional (92% malignant)
- Solitary or multiple and mostly occur in the body and tail
- Difficult to detect sonographically because of their small size
- Echo-free

METASTASIS
- Intra-abdominal lymphoma may cause a hypoechoic mass in the pancreas
- Enlargement of adjacent lymph nodes
CHAPTER VI

ULTRASOUND OF THE URINARY TRACT
Obajimi M

INTRODUCTION
In the past two decades ultrasound of the kidney has become a valuable and commonly performed examination. Initially ultrasound was used to evaluate renal masses to determine whether they were cystic or solid. Currently, the more common applications of renal ultrasound have been expanded to include:

- Evaluation of hydronephrosis
- Evaluation of the non-visualized kidney on excretory urography
- Evaluation of a flank mass
- Evaluation for a renal abscess

Although the sonogram is best performed with direct reference to a previous intravenous urogram in the case of a mass, it may be performed without the aid of the urogram when radiation exposure is unwarranted, such as during pregnancy, when the patient is allergic to radiographic contrast material, and also when poor renal function precludes an adequate intravenous urographic study.

In more recent years urinary tract ultrasound has been expanded to include investigation of the bladder and prostate, as well as the renal transplant. The clinical usefulness of this modality depends to a significant degree on how well the urinary tract structure and its surroundings are visualized. This in turn, is dependent on sonographic technique and the examiner’s knowledge. As with other organ systems, the use of the newer real-time systems has vastly improved and facilitated the ultrasound examination of the urinary tract.
Sonographic Technique
Preparation
There is no specific preparation required prior to a renal ultrasound examination. Occasionally sedation is necessary in very young pediatric patients. The requirement for sedation is much less frequent than in former years because the examination is primarily performed by real-time systems that can allow more movement on the patient's part without compromising the study.

Real-time Ultrasound Examination
The evaluation of the kidneys has by and large become a real-time examination. It is much faster to find the kidney, determine its long axis, and complete a satisfactory study using real-time systems. There is more flexibility as far as the real-time transducer is concerned and the system is portable, enabling the performance of high-quality studies out of the ultrasound laboratory.

The right kidney is best visualized with the patient supine or in the left lateral decubitus position using the liver as an acoustic window (Fig. 6.1). The left kidney is best scanned in the right lateral decubitus position using the spleen or fluid-filled stomach as an acoustic window. The right kidney may be best visualized by scanning in the anterior axillary line while the left may be best seen by scanning in the posterior axillary line. In the decubitus position, the true frontal plane of the kidney is viewed so that lesions in the kidney and perirenal spaces can be easily located. The coronal view additionally has the advantage of allowing easier differentiation between a parapelvic cyst and hydronephrosis. The medial and lateral borders of the kidneys are better visualized in the decubitus position.

![Figure 6.1: Normal kidney. A, Longitudinal view of the kidney obtained from an anterior approach demonstrates the hyperechoic renal sinus (s) completely surrounded by renal parenchyma. The cortical echogenicity is equal to that of the overlying liver (L). Several slightly hypoechoic renal pyramids (arrows) are seen at the junction of the renal cortex and renal sinus. The kidney has a relatively flattened appearance in this view. B, Transverse view demonstrates the renal sinus (s) extending to the renal hilum (h). In this view the kidney appears bulbous rather than flattened.](image)
Although it is possible to evaluate the kidneys in the prone position, there are more problems associated with optimal visualization in this position than in the decubitus positions. In the prone position, the paraspinal muscles may attenuate much of the sound beam and the lower ribs may also cast acoustic shadows, lending to a suboptimal examination. If the patient can only be scanned in the prone position, a pillow or rolled sheet placed under the anterior abdomen at the level of the kidneys will improve the renal image because the compression reduces the thickness of the soft tissues overlying the kidneys, thus lessening the sound attenuation. Also, the scattering and absorption of the sound beam will be reduced. Similarly, in the decubitus position, there is less interference from adjacent tissue and closer correlation with the functional anatomy of the kidney. In the prone or supine positions, the dorsal and ventral borders of the kidneys are better visualized. Scans are generally obtained in the position that allows optimal visualization. The primary positions are described above. If the patient cannot be examined in the decubitus position, then coronal scans through each flank can be obtained in the supine position. Most times it is helpful to examine the kidney in more than one position.

As with all ultrasound studies, the highest frequency transducer should be used that allows adequate visualization of the parenchymal detail in each projection. For adults, this is generally a 3-5 MHz transducer and in children, a 5-7.5 MHz transducer.

Optimal demonstration of renal parenchymal anatomy and renal mass lesions requires appropriate gain settings. The gain setting will vary with the kind of machine and transducer used. Determination of the gain setting therefore is a skill that requires a significant experience with the equipment. The operator must set the proper time gain compensation (TGC) to achieve even sized echoes throughout the homogeneous tissue. The gain should be high enough to fill the cortex but low enough so that the medulla is not obliterated.

There are several components to a complete renal ultrasound scan. Each kidney should be scanned carefully in the longitudinal and transverse planes. The maximum superior - inferior length of the kidney should be obtained during held inspiration. At least two measurements should be taken and averaged to increase precision. The renal cortical echodensity should be compared to that of the liver at a comparable level (Figs. 6.1) and density evaluated for uniformity.
The renal medullary pyramids should be identified in most patients. The corticomedullary junction is identified by the arcuate vessel interface. The renal sinus is central and echodense it should be evaluated for hydronephrosis. The renal artery and vein are best seen at the hilum in real time examination in the transverse and longitudinal planes. They may be multiple and may enter the kidney at different levels. These features are better defined by a Colour flow Doppler scan. The respiratory movement of the kidney should also be noted. Generally, the examination is complete if there is no renal mass. However in the presence of a solid mass, the examination is not complete without evaluation of the renal vein and the inferior vena cava, as well as the liver.

**Pediatric Examination**

It is critical to maintain body temperature, so heaters and warm gel may be required in cold ultrasound rooms. With portable units examination can be performed in the neonatal intensive care unit. Sedation is rarely indicated. At times it may be advantageous to examine the neonatal kidneys using a coronal approach. With this technique there is little manipulation of the infant, less hindrance from monitoring devices or tubes and improved visualization of the retroperitoneal structures due to less interference by bowel gas.

When evaluating a neonate with a renal mass it is important to examine the contralateral kidney because there is a high incidence of abnormalities as well as implications of bilateral disease. The enlarged kidney may function as a sonic window through which to view the contra-lateral one. With the baby in an anterior oblique position with the enlarged kidney anteriorly, longitudinal oblique scans via a flank approach can be performed.

**NORMAL ANATOMY**

The kidney is covered by a fibrous capsule closely applied but not adherent to the parenchyma. Surrounded by fat, the kidney is bounded anteriorly and posteriorly by the fibrous sheath, Gerota’s fascia and laterally the anterior and posterior leaves fuse to form the lateroconal fascia, which becomes continuous with the peritoneum along the abdominal wall. The perirenal space is closed superiorly and laterally and does not communicate across the midline. It is open or potentially open inferiorly. As such inflammation could track inferiorly or track back superiorly into the posterior pararenal space.
ADULT

Renal Cortex
The normal adult renal cortex is less echogenic than the liver but more echogenic than the adjacent renal pyramids (Fig. 6.1).

Renal Medulla
The renal pyramids are poor hypoechoic areas in the medulla and are usually 1.2-1.5 cm thick. They are surrounded by the more echogenic renal cortex. It is easier to see the pyramids in children and young adults. The renal columns of Bertin are cortical tissue extending into the space between adjacent pyramids.

Renal Sinus
The renal sinus contains the collecting system, renal vessels, lymphatics, fat and fibrous tissue. The renal sinus appears as an ovoid intense echo collection in the kidney on longitudinal axis and a rounded echodense area on transverse plane. If the collecting system is bifid, two lobulations of echodensity may be seen.

Normal Kidney Measurements
Measurements made with ultrasound are generally less than those made by radiography because there is neither geometric magnification nor change in size related to an osmotic diuresis from contrast. They are therefore more accurate. Both kidneys should be about the same size. In adults a difference of more than 2cm in length is abnormal.
- Length: up to 12cm and not less than 9cm
- Width: normally 4-6cm but may vary a little with the angle of the scan.
- Thickness up to 3.5cm but varies a little with the angle of the scan.
- The central echo complex (the renal sinus) is very echogenic and normally occupies about one third of the kidney.
- In the newborn, the kidneys are about 4cm long and 2cm wide.
- The renal capsule appears as a bright smooth echogenic line around the kidney
- Normal ureters are not always seen: they should be sought where they leave the kidney at the hilum. They may be single or multiple and may enter the kidney at different levels.

PEDIATRIC KIDNEY
In the normal neonate there is accentuated corticomedullary differentiation demonstrated up to the age of 6 months. The enhanced corticomedullary differentiation can be explained by an increase in renal cortical echo production possibly combined with a slight decrease in echo production from renal pyramids.
By age of two, the pediatric kidney takes on the adult sonographic features. Fetal lobulations are prominent features during the first two months of life and produce pronounced indentations of the renal contour. The ultrasound length versus the patient age is a useful screening tool if the patient is specifically referred for renal ultrasound.

The neonatal kidney ranges from 3.3-5.0cm (the left being 2-5 mm longer) with a width of 2-3 cm and a sagittal diameter of 1.5-2.5 cm.

Investigators have found the following formula useful in calculating normal renal length.

- >1year --- Renal length (cm) = 6.79 + 0.22 x age in years
- <1year --- Renal length (cm) = 4.98 + 0.155 x age in years.

Renal length is defined as the maximum mid-sagittal length.

**ABSENT KIDNEY**

If either kidney cannot be seen, search again Fig. 6.2. Adjust the gain to show the liver parenchyma and spleen and scan in different projections. Assess the size of the visible kidney. Hypertrophy of a kidney occurs at any age in a few months when the other kidney has been removed or is not functioning. If there is one large kidney and the other cannot be visualized after a careful search, it is possible that the patient has only one kidney.

![Image](https://via.placeholder.com/150)

**Figure 6.2. Renal agenesis. A, Longitudinal view of the right upper quadrant demonstrates shadowing bowel gas (b) posterior to the liver (l) but no identifiable kidney within the right renal fossa.**
If one kidney cannot be demonstrated, consider the following possibilities.

- The kidney may have been removed. Check the clinical history and examine the patient for scars.
- The kidney may be ectopic. Search the kidney area and the whole abdomen, including the pelvis. If no kidney is found, look for it in the chest. A contrast urogram may be necessary.
- If only one large but normal kidney is demonstrated, and there has not been any surgery, it is likely that there is congenital absence of the other kidney. If the only kidney visualized is not enlarged a failure to demonstrate the other kidney suggests chronic disease.
- If there is one large but distorted kidney, there may be a developmental abnormality.
- Apparent absence of both kidneys may be a failure to demonstrate them with ultrasound because of changed echogenicity resulting from chronic disease of the renal parenchyma.
- Any kidney less than 2cm thick and 4cm long can be very difficult to visualize, locating a renal vessel or ureter may be helpful in identifying the kidney, especially if the ureter is dilated.

RENAli ABNORMALITIES

Congenital
Multicystic Dysplastic Kidney
- There is a spectrum from unilateral Multicystic kidney through segmental and focal multicystic dysplasia, to bilateral multicystic kidney disease.
- It is the most common cause of an abdominal mass in the newborn.
- Usually unilateral
- The left kidney is affected twice as often as the right

The ultrasound findings of the classic multicystic kidney include
- cysts of varying shape and size
- absence of connection between adjacent multiple cysts
- presence of interfaces between cysts
- absence of identifiable renal sinus
- absence of renal parenchyma surrounding cysts and
- presence of eccentric echogenic areas (tiny cysts)

Unilateral hydronephrosis is a differential diagnosis of the ultrasound findings described with multicystic kidney (Fig.6.3).
Figure 6.3: Multiple anechoic, non-communicating cysts are seen in the left renal fossa. No normal renal structures are visualized.

**Infantile Polycystic kidney Disease**

This form of cystic disease is uncommon and inherited in an autosomal recessive fashion. The infant presents with organomegally secondary to large kidneys. The ecstatic tubules are so small that they are not seen with ultrasound.

**Adult Polycystic Kidney Disease**

Though bilateral may be unilateral or segmental. This form of polycystic disease is inherited as autosomal dominant with a high degree of penetration. The disease usually becomes clinically manifested in the fourth decade. Classically there is cystic dilatation of proximal convoluted tubules and Bowmans capsule as well as the collecting tubules. These cysts enlarge with age such that the patients present when renal function begins to decrease.

On ultrasound the affected kidney are enlarged with discrete cysts in the cortical region. The renal contour is also poorly demarcated. Ensure you scan the liver, pancreas and spleen for evidence of cystic involvement. Ultrasound is also useful in screening members of the family for undiagnosed polycystic disease that is not clinically manifested. (Fig.6.4)
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Figure 6.4: A. Cysts in polycystic disease have irregular walls and are variable in size. They distort the renal sinus echoes. A Classic sonogram for hereditary autosomal dominant polycystic kidney disease.

**Note:** Multiple cysts and large size. B. Longitudinal sonogram showing Multiple simple cysts. These have smooth walls, are not nearly as numerous, and vary less in size.

**Medullary Cystic Disease**
The ultrasound findings represent a spectrum of irregularly widened central echoes with small cysts and well defined cystic structures when larger medullary cysts predominate. The most characteristic ultrasound findings are small cysts confined to the medullary portions of the kidneys.

**LARGE KIDNEY**

* Bilateral Enlargement
  1. When the kidneys are enlarged but normal in shape, with normal decreased or increased homogeneous echogenicity, the possible causes are:
     - Acute or subacute glomerulonephritis or severe pyelonephritis.
     - Amyloidosis.
     - The nephritic Syndrome
  2. When the kidneys have a smooth outline and are uniformly enlarged with non-homogeneous hyperechogenicity, the possible causes are:
     - Lymphoma. This may cause multiple areas of low density, especially Burkitt lymphoma in children or young adults
     - Metastasis
     - Polycystic kidneys
Unilateral Enlargement
If one kidney appears to be enlarged but has normal echogenicity, and the other is small or absent, the enlargement may be due to compensatory hypertrophy. When no other kidney is seen, exclude crossed ectopia and other developmental abnormality. The kidney may be slightly enlarged because persistent segmentation with two or even three ureters. Search for the renal hilus: there are likely to be two or more vessels and ureters. A contrast urogram will clarify.

One Kidney enlarged or more lobulated than normal
The most common cause of an enlarged kidney is hydronephrosis which will appear on ultrasound images as multiple, well circumscribed cystic areas (the calyces) with a dilated central cystic area (the renal pelvis normally less than 1cm in width. Coronal images will show the continuity between the calyces and the pelvis. (Fig.6.5)

Figure 6.5: Variation in the appearance of hydronephrosis depending on transducer position. A, Longitudinal view of the kidney from an anterior approach demonstrates several cystic structures that are surrounded by hyperechoic renal sinus fat. In this single view these could represent dilated renal calices or peripelvic cysts. B, Longitudinal view of the same kidney from a lateral approach demonstrates multiple dilated renal calices and infundibula connecting to a central renal pelvis, confirming hydronephrosis.

In multicystic kidneys there is no such continuity. Always compare the two kidneys when assessing the size of the renal pelvis. When much of the pelvis is outside the renal parenchyma, it may be a normal variant. When the renal pelvis is enlarged, normal echoes can be lost because of the fluid content.
A large renal pelvis may be due either to overhydration with increased urinary output or to an overfilled urinary bladder. The renal calyces will be normal. Ask the patient to empty the bladder and rescan.

Pelvic dilatation can occur normally in pregnancy and does not necessarily indicate infection. Check the urine for infection, and check the uterus for pregnancy.

A large renal pelvis is an indication to scan the ureters and the bladder and particularly the other kidney to locate the obstruction. If no cause is identified, a contrast urogram will be necessary. The normal concave calyces may become inverted and rounded as the degree of obstruction increases. Eventually the renal cortex becomes thinned.

To assess the degree of hydronephrosis, measure the size of the renal pelvis when the bladder is empty, if the pelvis is wider than 1cm, but there is no calyceal dilatation, the hydronephrosis is mild. When there is calyceal dilatation, the hydronephrosis is moderate. If there is loss of the renal cortex it is advanced.

Hydronephrosis can be caused by congenital obstruction of the uretero-pelvic junction by ureteric stenosis as in schistosomiasis or a calculus or from an external pressure on the ureters by a retroperitoneal or abdominal mass.

**Horseshoe kidney**

This is a fusion anomaly, in which both kidneys are fused together in early embryonic life. Fusion anomalies of the kidneys can generally be categorized into 2 varieties:

- Horseshoe kidney and its variants
- Crossed fused ectopia Horseshoe kidney is probably the most common fusion anomaly.
The term horseshoe kidney refers to the appearance of the fused kidney, which results from fusion at one pole. In more than 90% of cases, fusion occurs along the lower pole (Fig. 6.6). Technically, the term horseshoe kidney is reserved for cases in which most of each kidney lies on one side of the spine. It includes symmetric horseshoe kidney (midline fusion) or asymmetric horseshoe kidney (L-shaped kidney) when the fused part, or the isthmus, lies slightly lateral to the midline (lateral fusion). Horseshoe kidney is generally differentiated from crossed fused ectopia in which both fused kidneys lie on one side of the spine and the ureter of the crossed kidney crosses the midline to enter the bladder.

![Figure 6.6: Horseshoe kidney. A Transverse sonogram showing the isthmus of a horseshoe kidney (arrows) crossing the midline in front of the spine. B. Horseshoe kidneys are located more centrally than other kidneys and are connected by the isthmus (i) be careful to recognize this appearance which could be mistaken for enlarged lymph nodes surrounding the aorta (a). C. A CT coronal reformat showing the isthmus at the lower renal poles.](image)

Ultrasonography can be useful for diagnosing this anomaly. The most important feature in establishing the diagnosis on ultrasound is the isthmus and its continuity with the lower poles. Other features, such as malrotation and an altered renal axis, may be difficult to evaluate at ultrasonography. In cases in which the isthmus is composed of only a thin fibrous band, this midline soft tissue may not be seen.

Findings such as a curved configuration of the lower poles, elongation of the lower poles, and poorly defined lower poles, suggest the presence of this anomaly. Other associated findings, such as stones, hydronephrosis, and cortical scarring, are reliably depicted on sonograms. Ultrasonography has also been useful in the diagnosis of this anomaly in utero.
In many patients, especially patients with a large body habitus; overlying bowel gas makes the acquisition of adequate scans difficult, for technical reasons. In cases in which the continuity of the poles with the isthmus cannot be clearly demonstrated, may result in a false negative study.

RENNAL MASSES

Renal Cysts

*Simple Cyst*
This lesion arises in the renal cortex and more often single than multiple, and may differ in size. It occurs in 50% of patients over 55 years (Fig.6.6). The etiology is unknown and it is not hereditary. It can be found anywhere in the kidney and usually unilocular with epithelial lining.

The classic cyst on ultrasound meets the following criteria:
- Has a clear wall demarcation
- Spherical or slightly ovoid in shape
- Absence of internal echoes
- Acoustic enhancement beyond the cyst margin

Rarely these cysts become infected or hemorrhagic, producing internal echoes. When this occurs or when the outline of any cyst is irregular further investigation is required.

There is 1 to 11.5% incidence of hemorrhage in a simple cyst; this incidence is greater in polycystic kidney disease.

An *Infected cyst* often contains internal echoes and patient is asymptomatic (Fig6.7). An *Atypical cyst* is usually septated like the Hydatid cyst (Fig6.8). Beside septations there may be cysts that contain calcium in their walls.

*Parapelvic cysts* are not true cysts but may be lymphatic in origin but with no communication with the collecting system (Fig6.9). In Tuberous Sclerosis, an inherited neurocutaneous disorder; the characteristic renal disorder is angiomyolipoma. However less common manifestation of the disease is intrarenal cysts.
Figure 6.7: Infected renal cyst. Longitudinal view of the kidney shows a well-defined mass with increased through-transmission but low-level internal echoes. These findings are consistent with either an infected or hemorrhagic renal cyst.

Figure 6.8: Atypical renal cyst septations. Longitudinal view of the lower pole of the kidney demonstrates a cystic mass with multiple internal septations. The septations coalesce centrally into a more solid-appearing component. Because of this, cystic renal cell carcinoma was considered a possibility. The lesion was resected and found to be a benign multiseptated cyst.

Fig.6.9: Peripelvic cysts simulating hydronephrosis. A, Longitudinal view of the kidney demonstrates multiple centrally located adjacent cysts (c). On no view was it possible to connect these cysts together or with a more central renal pelvis. Nevertheless, the possibility of Hydronephrosis was entertained.
Renal abscess on ultrasound appears as a well marginated anechoic mass, usually round or oval in shape with the wall being irregular and fine (Fig. 6.10). There may be debris within the lesion producing increased echoes. Characteristically, it demonstrates acoustic enhancement. An abscess may also show increased bright echoes due to micro bubbles of gas from gas-forming organisms.

To establish a definitive diagnosis an ultrasound guided aspiration of the lesion may be performed.

![Renal abscess](image)

Figure 6.10: Renal abscess. Longitudinal view of the kidney demonstrates a poorly marginated hypoechoic mass in the midportion of the kidney with bright specks within it (arrows). This proved to be a renal abscess following percutaneous drainage.

Co-existing cyst and tumour
The incidence of tumour and cyst is 2.1 to 7%. The tumour commonly plays an etiologic role in the cyst formation.

In the articles reviewed, none of these cystic lesions could meet all the classical ultrasound criteria and would be subject to further studies.

Solid Renal Masses
Renal masses may be well circumscribed or irregular and may alter the shape of the kidney. Renal echogenicity may be increased. The majority of malignant tumours are homogeneous, but when central necrosis occurs they become non-homogeneous. It is important to recognize normal or hypertrophied columns of Bertin, which can resemble a tumour. The echo pattern of the cortex should be the same as the rest of the kidney.
A complex non-homogeneous mass
The differential diagnosis of complex masses can be very difficult, but when there is spread of a tumour beyond the kidney, there is little doubt that it is malignant. As a tumour grows, its centre may become necrotic with a rough irregular outline and a great deal of internal debris, causing a complex ultrasound pattern. The differentiation of this from an abscess or a haematoma can be difficult. The clinical condition of the patient may indicate the proper diagnosis. Tumours can spread into the renal vein and inferior vena cava and resemble thrombosis.

Always scan both kidneys when a malignant renal tumour is suspected at any age, the liver and inferior vena cava should always be inspected and a chest radiograph obtained to rule out metastasis.

A rough irregular echogenic mass containing debris within an enlarged kidney may be malignant or a pyogenic or tuberculous abscess. The patient’s clinical condition may help to differentiate. In children malignant tumours may be bilateral, well encapsulated but not homogeneous. They may show calcification in the capsule. Haemorrhage or necrosis may change the echogenicity.

Renal Calculi
Not all calculi can be seen on plain radiograph of the abdomen and not all renal calculi can be detected by ultrasound. Ultrasonography has become an increasingly important technology for the detection of renal calculi. The sensitivity of ultrasonography is slightly superior to that of plain abdominal films. The renal calculi are detected by their marked echogenicity and associated acoustic shadowing. If clinical symptoms suggest calculi all patients with a negative ultrasound examination need intravenous contrast urography.

Calculi are mostly easily seen in the renal collecting system. The minimum detectable size on a general purpose ultrasound unit using a 3.5MHz transducer is 3-4mm diameter. Smaller stones 2-3mm may be seen with a 5MHz transducer. A calculus will be hyperechogenic with an acoustic shadowing. The calculus must be visualized in two different planes longitudinal and transverse, to permit accurate localization and measurement, this may avoid confusion with calcification in the renal parenchyma which may simulate calculus and give similar echo and shadow (Fig. 6.11).

Ureteric calculi are very difficult to locate by ultrasound. Failure to see a ureteric calculus does not mean that there is no calculus.
Figure 6.11: Renal calculus. Longitudinal scan demonstrating echogenic focus (arrow) within the renal parenchyma with an associated acoustical shadow (arrowheads).

TRAUMA
Trauma to the kidney may be blunt, penetrating or secondary to operative intervention. Renal trauma is generally managed conservatively with indications for surgery being on a clinical basis. Excretory urography is the radiologic modality most commonly used to evaluate trauma to the upper urinary tract.

The radiological classification of renal trauma is as follows:
- **Minor**: Normal urogram or one showing diminished renal concentration of contrast, a decreased nephrogram, minimal distortion of the calyces or blood clots in the pelvis.
- **Major**: Extravasation of contrast into perirenal tissue.
- **Catastrophic**: Non visualization of the kidney or marked deformity of the pelvicalyceal system with extravasation of contrast.

Though excretory urography is a satisfactory screening procedure it may fail to provide information of the full extent of renal injury. Nuclear medicine yields rapid assessment of the extent of parenchymal damage and reveals any significant injury to the renal pedicle.

The information available on ultrasound is anatomic and not functional. In a number of cases renal ultrasound may be normal, in some only blood clots are noted in the renal pelvis and the collecting system demonstrated as masses of low level echoes, separating the walls of the affected system.
A renal fracture is outlined by a linear reproducible absence of echoes in the area of a traumatized kidney. This should be differentiated from rib artifact where anechoic areas are seen anterior and posterior to the kidney and from a bifid collecting system. Bleeding into the retroperitoneal space may be seen as a sonolucency or sonodensity depending on the age of the bleed. Focal areas of internal hemorrhage and edema may be seen as hypoechoic areas. Urinomas produced by trauma can be seen as anechoic masses in a perirenal location.

Serial ultrasound may be used to follow up an injury identified on ultrasound.

**PERIRENAL FLUID**

*Blood, pus and urine around the kidney cannot be distinguished on ultrasound. All appear as an echo free area.*

**Retroperitoneal Masses**

Lymphoma usually presents as a hypoechoic, para-aortic or aorto-caval masses. If the gain is set too low it may resemble fluid. Any such mass can displace the kidney. A psoas abscess or haematoma can be echofree or complex: clotted blood will be hyperechogenic. If there is gas some areas may be hyperechogenic with acoustic shadows.

**Suprarenal Mass**

A renal scan must always involve the suprarenal region. This ensures evaluation of the adrenal glands. A suprarenal mass may be primary or metastatic tumour, abscess or haematoma. Most are well defined but may become complex, Adrenal haemorrhage is common in the newborn.

**Ultrasound of the Urinary Bladder**

Indications:
- Dysuria or frequency of micturition.
- Haematuria
- Recurrent infection (cystitis)
- Pelvic mass
- Retention of urine.
- Pelvic pain

*Always evaluate both kidneys when examining the bladder.*

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Preparation
The patient’s bladder must be full. Give 4 or 5 glasses of fluid and examine after about one hour. Alternatively fill the bladder through a urethral catheter with sterile normal saline but discontinue as soon as the patient feels uncomfortable. Avoid catheterization if possible because of the risk of infection.

Positioning of the patient
The patient should lie supine but may need to be rotated obliquely. The patient should be relaxed, lying comfortably and breathing quietly. Lubricate the lower abdomen with coupling gel. Hair anywhere on the abdomen will trap air bubbles therefore apply coupling gel generously.

Choice of transducer
Use a 3.5MHz transducer for adults. Use a 5 MHz transducer for children or thin adults.

Scanning Technique
Start with transverse scans from the pubic symphysis upwards to the umbilicus. Follow with longitudinal scans, moving from one side of the lower abdomen to the other. Any area that appears abnormal must be viewed in several projections. After scanning some patients may need to return after emptying their bladder to be rescanned. This is usually necessary to assess the post-voidal residual urine volume especially in patients with prostatic hypertrophy.

Normal Bladder
The full urinary bladder appears as a large, echo-free area arising out of the pelvis. The smoothness of the interior wall of the bladder and its symmetry in transverse section is usually assessed. The thickness of the bladder wall will vary with the degree of distension but should always be approximately the same all around the bladder. Any local area of thickening is abnormal. The presence of trabeculation or diverticula should also be ruled out. When fully distended, the normal bladder wall thickness is less than 4mm thick.

Normally, there should be no residual urine: if there is, the volume should be estimated by using the formula for an ellipsoid:
\[(A \times B \times C) \text{ cm} \times 0.52\]

This measures the milliliters (cubic centimeters). A value greater than 100ml is significant. When the bladder has been thoroughly examined, the kidneys and the ureters should also be evaluated.
Abnormal bladder

It is important to scan for:

- Variation of the bladder wall thickness and trabeculations.
- Asymmetry of the bladder.
- Cystic masses in or outside the bladder (ureterocele or diverticulum)
- Solid masses within the bladder or at the base of the bladder

Generalized thickening of the bladder wall

1. **Chronic Prostatic Obstruction:** In elderly men, bladder wall thickening is usually the result of chronic prostatic obstruction. If suspected the prostate and kidneys are evaluated to exclude hydronephrosis by scanning the ureter and the kidneys. Associated diverticula may be present. These project outwards from the margins of the urinary bladder and are only visible if greater than 1cm in diameter. Diverticula are usually echo-free with good sound transmission. Sometimes the opening of a diverticulum can be demonstrated: Diverticula may collapse or increase in size after micturition.

2. **Severe, chronic infection/cystitis:** The inner wall of the bladder may be thickened and irregular. This may be extensive and involve other parts of the renal tract.

3. **Schistosomiasis:** The bladder wall may be thickened, with increased echogenicity and scattered dense (bright) areas due to calcification. The calcification varies in nature and may be discontinuous and patchy with different thickness. The calcification is in the intramural ova and does not prevent normal bladder contraction.

   Poor bladder emptying indicates superimposed active bladder infection, or prolonged or recurrent infection. The extent of the calcification does not indicate the activity of the schistosomal infection, and calcification may decrease in the latter stages. However the bladder wall usually remains thickened and does not easily distend. There may also be hydronephrosis.

4. **Urethral Valves:** Very thick trabeculated bladder walls in children may result from outlet obstruction caused by urethral valves or urogenital diaphragm.

5. **Neurogenic Bladder:** A thickened bladder wall may occur in neurogenic bladder and will usually be associated with uretero-hydronephrosis.

Localized thickening of the bladder wall

Whenever localized bladder wall thickening is suspected multidirectional scans are needed, particularly to exclude a polyp. Moving the patient or increasing the volume of fluid in the bladder will help to identify bladder folds (folds will disappear as the bladder distends). If there is any doubt, the scan is repeated after 1 or 2 hours. The patient is not allowed to micturate before the examination is repeated.
Differential diagnosis of localized bladder wall thickening

- Bladder fold; due to incomplete filling.
- Bladder neoplasm: usually are multiple but located in one area.
- Calcification maybe found in the tumour or bladder wall as bright echoes.
- Bladder polyps; sessile or mobile on the stalk, single or multiple.
- Localized infection: granulomas, e.g tuberculosis cause multifocal but localized thickening. The bladder is often small and unlike tumours becomes painful when distended. Schistosomiasis may cause multiple flat plaques and polyps. Reinfection in children can produce an acute urticarial reaction in the bladder wall causing marked local bladder mucosal thickening. This subsides with treatment.
- Trauma: in this instance scan the pelvis to exclude fluid (blood or urine) outside the bladder. The scan should be repeated after ten days when wall thickening may have decreased.

Intravesical blood clot and tumour look alike and both may be associated with haematuria

Differential diagnosis of abnormal density within the bladder

A. Attached to the wall

- **Polyp**: change patient position and rescan.
  
  *Adherent Calculus*: calculi may be single or multiple, small or large, but with an acoustic shadowing may become adherent to the bladder wall. Scan patient in different planes to assess movement.

- **Ureteroceles (Fig. 6.12)**: usually presents as a cystic mass within the bladder near a ureteric orifice. It may change in size with repeat scans and may be so large to obstruct the opposite ureter. It may also be bilateral but seldom symmetrical. If suspected the kidneys and ureters are scanned to rule out other congenital anomalies.

- **Enlarged prostate (Fig. 6.13)**: an echogenic/hypoechoic, non mobile mass located centrally at the base of the bladder in a male patient. In women an enlarged uterus can also distort bladder density.
B. Mobile density within the bladder.

- Calculus; except when they are large they move within the bladder and can be confirmed by rescans in different planes
- Foreign body; catheters rarely
- Blood clots; a thrombus can resemble a calculus
- Air; introduced either through a catheter, an infection or a fistula, usually echogenic, mobile and non dependent.

Figure 6.12: A. Longitudinal sonogram showing a well rounded cystic mass (arrow) in the wall of the urinary bladder consistent with a ureterocele. B. IVU demonstrates the cobra head appearance of the ureterocele with associated dilatation of the ipsilateral ureter.

Figure 6.13: Enlarged prostate extending into the urinary bladder.

**Large (overdistended) bladder**

- When distended, the bladder walls will be smooth and evenly stretched with or without diverticula. Measure the bladder volume to confirm suspected overdistension
- Always look at the ureters and check the kidneys for hydronephrosis.
- Ask patient to empty the bladder before evaluating urinary residual volume
Common causes of bladder distension
- Enlargement of the prostate
- Urethral stricture
- Urethral calculus in the male
- Bruising of the urethra in the female (honeymoon urethritis)
- A neurogenic bladder
- Urethral valves or diaphragm in newborn infants
- Cystocele in some patients

Small Bladder
A bladder may be small because of cystitis, which prevents the patient from holding urine and present with a clinical history of frequent and painful micturition.

The bladder may also be small because the walls have been damaged or fibrosed, reducing the bladder capacity. Though micturition may be frequent it is not painful.

Sonographic Features
- Bladder is small in several planes despite intake of more fluid
- Irregular and thick bladder wall from fibrosis

A small bladder may be due to:
- Late schistosomiasis
- Recurrent cystitis
- Tumor infiltration
- Radiotherapy or post tumour resection

Interventional procedures
Renal Biopsy may be valuable in determining the cause of post transplant oliguria and differentiating rejection and Acute Tubular Necrosis. It is invasive and could lead to further deterioration of function. The procedure of renal biopsy is generally performed with ultrasound guidance. It is ideal for ultrasound guidance since the kidney lies superficially in the iliac fossa. The superior lateral aspect of the kidney is localized provided the kidney is placed in a cephalad – caudad orientation. The target area is localized and marked on the skin or the nephrologists may be guided directly with real-time visualization and a biopsy needle guide. The latter decreases the number of attempts, increases the tissue recovery and decreases the time of the procedure. Once the needle is seen to enter the kidney the needle is detached from the needle guide and the biopsy is performed “free-handed”.

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Other Interventional Procedures
Besides renal biopsy, other interventional urologic procedures include:
   ❖ Ultrasound guided antegrade pyelogram
   ❖ Ultrasound guided percutaneous nephrostomy
   ❖ Aspiration and fluid drainage

Sickle Cell Anaemia
Sickle cell anemia causes abnormalities in the abdomen relating to haemolytic anaemia in liver, gallbladder, spleen and the kidneys.

Renal: Renal enlargement is seen with medullary or diffuse increase in reflectivity (increase in medullary echogenicity). Other manifestation include renal papillary necrosis as well as multiple rounded or triangular cystic spaces communicating with the collecting system in the modularly region without a dilated renal pelvis.
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CHAPTER VII

UTRASOUND OF THE GASTROINTESTINAL TRACT

G.I. Ogbole and M.O. Obajimi

“Evaluation of the GI tract is the ‘last frontier’ for the sonologist who really enjoys a challenge”

INTRODUCTION

Over the years, ultrasound has evolved to be a useful tool for initial evaluation of the gastrointestinal (GI) tract. Improvements in ultrasound resolution and the increasing familiarity with sonographic findings have also broadened its applications. Today, the spectrum of indications for GI ultrasound is varied from acute conditions such as appendicitis to a number of subacute and chronic diseases. The GI tract can be examined by either the transabdominal or endoluminal approach.

In this chapter, we would focus on the transabdominal approach. The cross sectional ability of ultrasound [similar to computed tomography (CT) and Magnetic Resonance Imaging (MRI)] to evaluate the transmural inflammatory or neoplastic changes within its surrounding structures is a major advantage over endoscopy and contrast radiography. This capability contributes considerably to achieving accurate diagnosis and aids in monitoring disease activity and progression.

Advantages of GI ultrasound

- It provides more detailed information on bowel wall layers than CT
- It allows evaluation of the entire gastrointestinal wall rather than just the mucosa
- It yields more consistent wall thickness measurements
- It gives real-time assessment of motility without ionizing radiation
- It can guide sampling/biopsy of diseased tissues
- Widely available, even in developing countries
- It’s a non-invasive procedure
- Absence of demanding preparation (other than a recommended 12 hour fast)
Limitations of GI Ultrasound

- The entire intestinal tract cannot consistently be evaluated, especially the small bowel.
- Many of the findings are nonspecific.
- Obtaining and interpreting the images is highly operator dependent.
- Image quality is often degraded and poor in obese patients.
- The presence of bowel gas may furthermore hinder demonstration of relevant structures.

Familiarity with the normal and abnormal ultrasound appearance of the GI tract provides a marked advantage in the diagnosis of GI disease. It should be noted that ultrasound of the GI tract does not preclude the need for abdominal radiographs. The two imaging modalities are complementary, and each adds individual information.

Techniques and approaches vary somewhat on patient conformation and position. Scanning the patient in supine position allows relatively complete evaluation of the GI tract, although right and left lateral decubitus may be necessary to redistribute gas and fluid within individual portions of the stomach and bowel. Right lateral intercostal windows are often helpful in visualizing the pylorus and proximal duodenum.

Ultrasound is currently the first imaging study performed in patients with abdominal pain in many developing countries, where access to expensive tests such as CT is limited, and the body mass index (BMI) of the population is fairly low, allowing a reasonable view of the GI tract. The knowledge of the sonographic appearance of diseases of the GI tract is essential, predominantly in acute abdomen cases. It is important to be aware of the variable ultrasound appearances of normal bowel, as it may be responsible for mimicking other pathology. Normal bowel is frequently difficult to examine on ultrasound as the gas-filled lumen reflects the sound, requiring careful compression techniques. However abnormal bowel is particularly accessible to ultrasound. A fluid-filled lumen also makes easy the demonstration of valvulae conniventes of the small bowel and haustra of the large colon.

This chapter provides an overview of the sonographic appearance of the GI tract anatomy and some commonly encountered lesions in daily practice.
Technical Considerations and Examination Technique

Complete imaging of the GI tract requires both low (2-5 MHz) and high-frequency (5 to 15 MHz) linear or convex probes. Tissue harmonic imaging allows better delineation of wall layers. Modern technical equipment also includes Colour and Power Doppler imaging. Panoramic imaging may also be useful in visualization of longer portions of the intestine.

Patients should be scanned with both a 2- to 5-MHz curvilinear transducer and a 5- to 12-MHz linear transducer. A 12 hour fast is recommended for routine cases. For accurate visualization of the stomach, a cup of water may be given to patients suspected to have stomach or upper GI disease. If duodenal disease is suspected, scanning in the right lateral decubitus position should also be performed. Colour Doppler interrogation may be used to evaluate vascular aetiologies of lesions.

Examination of the gastrointestinal tract should start with a systemic survey using the probe to get an overview over the different parts of the gastrointestinal tract. Subsequently examination proceeds with a high-frequency probe to obtain details and focus on the actual problem. In patients with localized abdominal pain the examination can initially be focused on this area.

The stomach is scanned in longitudinal and transverse sections via a subxiphoidal approach from the cardia to the pylorus. Using the left lobe of the liver as acoustic window and provided good conditions exist, it is possible to scan the distal oesophagus by tilting the probe cranially in the epigastrium. The fundus of the stomach can be demonstrated in a transverse view. The duodenum (Fig1a-b) is identified by its “C-shaped” course around the pancreatic head and by the location of the third part of the duodenum which lies between the aorta and the superior mesenteric vessels.
Figure 7.1. Normal Duodenum. (a) Transverse view at the level of the pancreatic head showing fluid-filled duodenum (black arrow) adjacent to the pancreatic head. Notice the hyperreflectivity of the posterior wall due to possible air contents. (b) Transverse view at the same level showing the 2nd part of the duodenum in an oblique orientation (black arrow). PV = Portal vein, IVC = Inferior vena cava, ST = Stomach.

The small bowel cannot be evaluated continuously. Systemic examination is performed by making vertical, parallel, and overlapping planes with the transducer. The jejunum is usually located in the left upper and mid abdomen and the ileum in the right mid and lower abdomen. The right iliac vessels are a landmark of the ileocecal region. Fluid-filled small bowel loops allow optimal visualization of the valvulae conniventes (Fig. 7.2).

Figure 7.2. Sonographic appearance of the normal small bowel. Magnified transverse image at the level of the hypogastrum showing prominent mucosal folds indicative of a loop jejunum (arrows).
It is imperative to examine the colon in a systemic way. This may be done in transverse sections for each segment. Starting from the ascending colon in the right upper quadrant and followed to the ceacum or in reverse order. Then the colon is followed from the right colonic flexure along the transverse colon to the splenic flexure. The descending colon is identified by its laterodorsal position and scanned caudally to the sigmoid colon which takes a variable course over the left iliac vessels into the pelvis. The rectum is visualized an identified through a filled urinary bladder (Fig. 7.3).

Figure 7.3. Rectum. Transverse view using the under-filled urinary bladder (B) acting as a window to visualize the rectum in a patient. Notice the fairly rounded prostate gland (P) at the bladder neck with homogenous echogenicity.

Normal Sonographic Appearance of the Bowel
The normal bowel wall is seen as a multilayered ‘Rugger-jersey’-like area with hyperechoic bowel content at the center. Five distinct layers can be depicted on sonography:

1. An inner hyperechoic layer, which is the interface between the mucosa and the bowel contents
2. A hypoechoic layer, which is the deep mucosa
3. A hyperechoic layer, which is the submucosa
4. A hypoechoic layer, which is the muscle proper
5. An outer hyperechoic layer, which is the serosa and the serosal fat (Fig. 4a-b)

Wall layers are best examined with a high-frequency transducer (8-12MHz).
Figure 7.4a. Normal bowel layers. Long axis view of the stomach showing the various distinct layers using a high resolution frequency transducer. These layers are similar in all parts of the bowel but more distinctly demonstrated in the stomach. 1 = Echogenic mucosal interface, 2 = Hypoechoic deep mucosa and muscularis mucosa, 3 = Echogenic submucosa, 4 = Hypoechoic muscularis propria, 5 = Echogenic serosal interface. Fig 4b. Schematic diagram showing the typical appearance of the bowel layers as visualized on Ultrasound. Notice the muscularis (*) layers (mucosa and propria) are both hypoechoic.

**Sonographic Appearance of the oesophagus**
The oesophagus is only rarely identified sonographically at the level of the cardia especially when fluid filled.

**Sonographic Appearance of the Stomach**
The normal stomach wall measures 3 to 6 mm (non-distended) (Fig.7.5) and 2 to 4mm (distended).

Thickening can be due to neoplastic or inflammatory causes, and thickening of greater than 1 cm is generally considered to be due to malignancy. All five layers of the stomach wall are generally distinguishable. Artifactual thickening may occur due to rugal folds, imaging plane, and degree of distension. Rugal folds are seen when the stomach is empty and tend to disappear when the stomach is distended. Visualization of the stomach can be improved by asking patient to drink about 300-500ml of water during the scan.
Figure 7.5. Normal stomach wall thickness measurement. View of the un-distended stomach mucosa showing normal measurement using callipers shown with double-head arrows.

**Sonographic Appearance of the Small and Large Bowel**

Complete assessment of the small intestine includes assessment of the size, shape and wall thickness. The transverse axis is often preferable for measuring as there is less chance of error. Measurements are more accurate when wall layers can be seen so that callipers can be precisely placed. Wall thickness and luminal diameter do vary with peristalsis. The intestines have an average wall thickness of 5±1mm (non-distended) and 3±1mm (distended). Non identification of the wall layers does not necessarily indicate pathology.

Intestinal contractions are generally 1-3 per minute. Using the spleen as an acoustic window may enhance imaging of the intestine. Wall thickening is most easily detected when asymmetric.

The appearance of the small bowel on sonography depends not only on the structure of the individual segment but also, more importantly, on its contents and degree of distension.

The bowel may be collapsed, containing only a small amount of mucus (mucus pattern or may contain fluid or gas (Fig. 7.6).

The mucus pattern is seen as a target appearance with a highly reflective core of mucus. The fluid pattern gives a tubular appearance on a longitudinal section and a rounded pattern on a cross section.
The jejunum has valvulae conniventes, which give a ladder pattern, and the ileum has smooth, featureless walls.

The site of the involved bowel can only be inferred from the location of the bowel loop. The large bowel has a similar appearance but the wall layers of the colon are not easily identified; however, it can be distinguished by its location in the paracolic regions and the presence of haustra (Fig. 7.7).

Figure 7.6. Fluid-filled bowel. Transverse view of a section of the ileum (black arrow) showing mixed echogenic food contents.

Figure 7.7. Large Bowel. A short axis section of the colon (white arrows) with echogenic contents.
This is identified as colon because of its unique haustral markings (black arrow), seen here as an echogenic band.

**Appendicitis**
The appendix is a blind-ending, tubular structure that arises from the cecum. The normal appendix shows the different wall layers similar to the rest of the intestine, frequently courses from the iliac fossa medial and caudal over the iliopsoas muscle, is oval shaped under compression, and contains some gas or fecal material.

The position of the appendix can be variable and may even be retroceacal and the location of the cecum may also vary.

Acute appendicitis is one of the most common causes for acute surgery worldwide. Because less than half of patients present with typical clinical symptoms, appendicitis remains a common clinical problem.

Peak age incidence is between 20 and 30 years.

**Aetiology**
Appendicitis is often triggered by luminal obstruction due to infectious swelling of the wall or obstruction by fecoliths, lymphatic hyperplasia, food remnants, foreign bodies, stricture, tumour, parasite and rare causes like Crohn’s disease.

Increase in intraluminal pressure, tissue damage, and pathogen entry into the appendiceal wall lead to transmural inflammation.

**Sonographic Findings in appendicitis**
These findings are 77-94% sensitive, 90% specific, and 78-96% accurate.

- Point of maximum probe tenderness over the appendix
- Visualization of non-compressible appendix as a blind-ending tubular aperistaltic structure (seen only in 2% of normal adults, but in 50% of normal children)
- Target appearance of >6 mm in total diameter on cross section (81%)
- Mural wall thickness >2 mm
- Hyperechoic changes of the surrounding fatty tissue, mesoappendix / pericecal fat
Hypoechoic changes and fibrinopurulent exudate
Adjacent bowel loops such as the cecum and terminal ileum are thickened
Lumen may be distended with anechoic / hyperechoic material
Loss of definition of wall layers
Visualization of appendicolith (6%)
Localized periappendiceal fluid collection

Colour Doppler ultrasound may show increased prominence from increase in the size and number of vessels in and around the appendix. There may also be decreased resistance of arterial waveforms and a pulsatile venous flow.

**Bowel Obstruction**

Patients with clinical signs of bowel obstruction such as abdominal pain, abdominal distension, and vomiting need immediate diagnostic evaluation. Ultrasound has been found to be helpful in the investigation of acute obstruction. It can confirm obstruction, by demonstrating dilated, fluid-filled bowel loops with ineffective peristalsis. These fluid-filled loops of bowel are highly amenable to ultrasound scanning, which has the advantage of real time visualization of peristalsis, distinct from abdominal radiograph. It is possible to trace the dilated bowel to the site of obstruction, distal to which are normal loops of collapsed bowel.

The confirmation of obstruction with ultrasound has been proved to be as sensitive as and more specific than plain X-rays and can potentially reduce the need for surgery in such patients, minimise costs and eliminate the effect of radiation dose on the patient. However, identifying the actual site and cause of obstruction may be time-consuming and frequently unsuccessful. Patients with suspected bowel obstruction, therefore, in such circumstance may need to proceed straight to CT or in this environment fall under the surgeon’s knife for exploratory laparotomy.

However in experienced hands the level of obstruction can be quickly determined by careful analysis of dilated bowel segments. The duodenum usually can be seen next to the pancreatic head and the third part can be recognized because it passes to the left side posterior to the superior mesenteric vessels.

The dilated jejunum can be distinguished from the ileum by the pattern of the valvulae conniventes and to some degree by the location in the abdomen. The colon is identified by its typical haustration (Fig 7.7).

Moreover, the ascending and the descending colon are fixed to the retroperitoneum laterodorsally in the abdominal cavity.
Hypertrophic Pyloric Stenosis
Hypertrophic pyloric stenosis is a familial condition commoner in boys (M: F=4:1). It is also more prevalent among Caucasians. It is a condition characterized by hypertrophy and hyperplasia of the circular muscle, which result in elongation of the pylorus and constriction of the canal.

The typical patient is a neonate presenting with projectile vomiting in the second or third week of life. The hypertrophied muscle may be palpated as an abdominal mass by in over 40% of cases.

The diagnosis of pyloric stenosis is usually established with a good clinical history. (With a patient of the appropriate age, history of projectile vomiting, observation of peristaltic wave crossing the anterior abdominal wall, and palpation of the pyloric ‘olive’, there is sufficient indication for surgery.)

When the clinical findings are unclear, imaging studies are necessary for the diagnosis. When in doubt, the UGI series is the diagnostic imaging procedure of choice, in spite of an error rate of about 10%, use of ionizing radiation and introduction of additional fluid into the already obstructed stomach.

A few authors advocate real-time ultrasound as the initial imaging procedure of choice, with its the advantage of visualizing the hypertrophied muscle directly. The lesion is seen usually as a target medial to the gall bladder, anterior and caudal to the portal vein, anterior to the kidney, and lateral to the head of the pancreas.

The wall or hypoechoic rim represents the hypertrophied muscle. Normally, the wall thickness is less than 4mm, with a diameter of less than 10mm. A diagnosis of pyloric stenosis can be made if the rim measures > 4 to 4.5mm, and/or the diameter is ≥ to 13 to 13.4mm. The target lesion associated with pyloric stenosis is located by orienting the transducer in a longitudinal plane. By aligning the transducer with the long axis of the pyloric channel, the most diagnostic images are obtained. This alignment displays the continuity of the mucosal and muscle layers between the stomach and pylorus and depicts the characteristic elongated pyloric channel as a mucosal double-track sign, such as described on barium studies (Fig. 7.8).
Figure 7.8. Hypertrophic pyloric stenosis. Schematic diagram showing the thickened pyloric muscles with a narrowed channel. The typical sonographic features are a muscle thickness at the pylorus of at least 4mm and a channel length of at least 16mm.

The length of the thickened segment is usually equal to or greater than 16 mm, (normal < 15mm).

Indirect signs of pyloric stenosis on ultrasound include:

- Obstructed fluid-filled stomach,
- Exaggerated peristaltic waves
- Failure of fluid to pass from the stomach into the duodenum
- Failure to image the descending duodenum.

Known morphologic changes associated with pyloric stenosis include;

- Impingement on the fluid-filled antrum,
- Prepyloric antral thickening,
- Extensive fluid in the proximal portion of the pyloric canal,

If the ultrasound is negative, or equivocal, the UGI series may be performed. Non visualization of the pylorus is strong evidence against pyloric stenosis. Ultrasound is useful in monitoring patients after surgery. The pyloric wall found may return to normal (4mm) as early as 6 weeks post surgery.

**Intussusception**

Intussusception is the most common cause of obstruction in children; it is fairly uncommon among adolescents and adults. In over 75% of adult cases, there is an identifiable bowel lesion at the leading point. When located in the colon, 50% of such lesions may be malignant, whereas in the small bowel the majorities are benign.
The clinical presentation of intussusception is varied and nonspecific. It may have a protracted course, with symptoms present for greater than 3 months. As the intussusceptum progresses into the intussuscipiens, the bowel wall becomes oedematous. The intussusceptum is telescoped into the intussuscipiens until it can go no further owing to traction on the mesentery, which is dragged between the entering and returning walls of the intussusceptum. Venous obstruction ensues with exudation of fluid and resultant wall edema. The edema is greatest at the apex of the intussusceptum, but extends to involve the entering and returning intussusceptum walls.

**Clinical presentation**

**Acute:** Abdominal pain, vomiting, and rectal passage of blood and mucus and ‘currant jelly’ stools.

**Chronic:** (mainly adults), mild abdominal pain, diarrhoea and less frequently, vomiting, abdominal mass/swelling in up to 85%.

Ultrasound may provide sufficient evidence for the diagnosis even in atypical cases and, in acute cases; it may assist in hydrostatic reduction.

**Ultrasound features**

A target-like or bull’s eye pattern is seen on transverse scan *(Fig.7.9).* *The thickened hypoechoic rim represents the edematous intussuscipiens that surrounds the hyperechoic centre, which is due to multiple interfaces of compressed mucosal and serosal surfaces of the intussusceptum.*

The target lesion seen on ultrasound is nonspecific and can appear following primary or secondary cancer, lymphoma, Crohn’s disease, inflammation due to pancreatitis, bowel infarction, radiation ileitis, and hematoma.

A scan of the long axis helps to make a more definite diagnosis of intussusception *(Fig.7 10).*

On a cross-section through the apex of the intussusceptum, the more common target lesion is seen *(Fig.7.11)* with a very thick hypoechoic rim due to the severe oedema of the entering and returning intussusceptum walls and resultant obliteration of the interface between them. When scanning through the more proximal portion where the parietal oedema is less severe, an image of two concentric rings and an inner circular area is seen. The outer and inner rings represent the returning and entering walls of the intussusceptum; the intermediate hyper reflective ring separates the walls, due to changes in the interface between them. When the long axis is scanned, three parallel stripes of low echogenicity are delineated as well as two reflective areas.
Figure 7.9. Intussusception: sonographic transverse image showing the concentric ‘target’ appearance through an intussusception (black arrow indicates the intussusceptum within the intussucipiens (white arrow))

Figure 7.10. Intussusception. Long axis view of a loop of small bowel within another loop which helps to make a definite diagnosis of Intussusception.
Figure 7.11. Intussusception. Transverse section in the region of the hepatic flexure showing the apex of an intussusceptum with a hyperechoic concentric ring surrounded by hypoechoic margin giving the typical Doughnut or Target sign.

Gastric Outlet Obstruction

Causes of Gastric outlet obstruction

- Chronic duodenal ulcer
- Tumours of the stomach
- Pancreatic head tumours

Plain x-rays are frequently false negative in these cases as vomiting results in lack of air in the obstructed segment.

Ultrasound easily depicts the dilated stomach with ingested food and fluid-fluid levels (Fig. 7.12). The dilated duodenum or the dilated segment in an afferent-loop syndrome is also reliably demonstrable.

Delayed gastric emptying may also be caused by inadequate peristalsis due to a number of diseases.
Gastric Outlet Obstruction. Transverse view at the level of the epigastrium showing the dilated stomach in a patient with a known pancreatic head tumour (not shown in this view).

Gastric, Small and Large Bowel Tumours

Carcinoma of the Stomach

Carcinoma of the stomach is the most common neoplasm of the upper GI tract. Over 90% of malignant tumors of the stomach are carcinomas, with 3% being lymphoma. Gastric carcinoma is commoner in Japan than any other country but appears to be rising among people of African descent and is generally commoner in males.

Globally, one half of these tumors occur in the pylorus and about 25% occurs in the body and fundus of the stomach.

Tumours are seen as localized thickening of the inner layer with hypoechoic tissue, which then progresses to loss of the layered structure and circumferential thickening. Growth patterns can be polypoid, fungating, ulcerated, or infiltrative.

Seventy-five percent of these tumors occur in patients older than 50 years.

The clinical manifestations are nonspecific, with a quarter of patients presenting with a palpable mass.

On ultrasound, the examiner looks for the typical target or pseudo-kidney ascribed to GI lesions. While the target lesion may be seen with tumor, it also may be secondary to lymphoma, metastatic disease, caustic gastritis, pancreatitis involving the stomach, and chronic granulomatous disease of childhood.
Identification depends on the type of tumor, its location, and extent. It may be seen as a large mass in the left upper quadrant or a gastric wall thickening. This wall thickening may be localized or diffuse. With localized thickening, the wall is eccentrically thickened. The wall may have a C-shaped appearance when only the involved wall is delineated. When ultrasound demonstrates a mass, it usually indicates significant infiltration of the mucosa and muscularis and/or exogastric extension. An antral carcinoma may present with gastric dilatation due to obstruction. This gastric dilatation may also be secondary to pylorospasm, inflammation, intrinsic or extrinsic tumor, electrolyte imbalance, diabetes, neurologic disease or medication.

Besides identifying the gastric primary tumor, ultrasound may be used for staging.

When such a patient is referred for evaluation of liver metastases, it is worthwhile to gather additional information about extent of the tumor. This is done by performing a complete sonographic examination of the abdomen and pelvis and by attempting to visualize the primary neoplasm and its relationship to surrounding organs. This carcinoma may spread to the surrounding gastric wall and adjacent organs and structures directly, or it may spread via lymphatics to perigastric lymph nodes.

Small-Bowel Tumours
The small bowel is more commonly affected by lymphoma than the large bowel. The appearance of small-bowel involvement in primary and secondary non-Hodgkin lymphoma is similar.

On ultrasound, these tumours are hypoechoic and show a variety of growth patterns, including circumferential wall thickening as well as nodular or bulky tumour spread. The bordering mesentery may show enlarged lymph nodes.

Colorectal Cancers
Colonic carcinomas have 2 typical sonographic appearances.
- Localized hypoechoic mass with an irregular shape and lobulated margins.
- Segmental circumferential thickening of the colonic wall.

The intraluminal gas may appear as a cluster of high reflectivity due to areas of ulceration. To make a diagnosis, Shirahama et al described 4 sonographic findings
- Localized irregular thickening of the colonic wall,
- An irregular contour,
- Lack of movement or change in configuration on real-time scanning,
- Absence of a layered appearance of the wall.
Perforation

Perforation of the GI tract should be the diagnosis when gas is detected in the peritoneal cavity. Ultrasound is said to be more sensitive than plain film for diagnosing pneumoperitoneum, but CT is the gold standard regarding accuracy.

Pneumoperitoneum is seen as a hyperechoic line or as small gas bubbles with reverberation artefacts between the visceral and the parietal peritoneum. This is best visible anterior to the liver surface or immediately below the anterior abdominal wall in the supine position or left decubitus position. Extraluminal gas moves by changing the patient’s position and disappears when pressure is increasingly applied. Similar to plain film, a short time frame may occur after changing the patient’s position before small amounts of gas move to typical areas and become visible on sonograms.

Pneumoperitoneum and extraluminal fluid are seen in the upper abdomen as a consequence of gastric or duodenal perforation. Gastric or duodenal ulcers are the most common causes are perforation. Evidence of gas in the fissure for ligamentum teres is a further hint and may be the single sign in cases of contained perforation.

If perforation of the small bowel occurs, extraluminal fluid with bright echoes and extraluminal gas are the predominant features. Some of the causes of perforation are foreign bodies, ischemic disease (gangrene), and blunt trauma. Pneumoperitoneum is also the predominant sign in colonic perforation. Two thirds occur due to diverticulitis. Other causes include colonic ischemia, bowel obstruction, perforated neoplasm, or iatrogenic perforation.

Conclusion

Ultrasound is an invaluable resource due to its ease and versatility in achieving diagnosis for possible GI lesions. However it should not be used to replace but complement barium studies and gastroscopy in the diagnosis of GI disease. Since it is usually performed as the first diagnostic procedure, GI ultrasound helps streamline the patient’s workup and provides alternative minimally-invasive management through its ability to guide interventional procedures.
References

11. Lim JH. Colorectal cancer: sonographic findings. AJR 1996; 167: 45-47
INTRODUCTION
A clear knowledge of the anatomy and physiology of blood circulation in the abdomen is necessary for proper understanding of ultrasound (US) vascular applications in the abdomen. Some organs like the liver and spleen are superficial and easily accessible. Others like the pancreas are deep and retroperitoneal. A combination of factors comes to play in order to optimise image acquisition and display. A linear, curvilinear or sector probe may be needed depending on the acoustic window available to examine a particular structure. Importantly, superficial and deep structures require high and low frequency transducers respectively for optimum acquisition of colour Doppler signals and display of flow direction. Excessive bowel gas and subcutaneous fat are limitations to adequate visualization of vascular structures. When an organ is deeply situated, the depth can be reduced by compression using the ultrasound probe.

Just as in routine US examination, a patient for abdominal vascular study should also fast overnight for clear demonstration of hepato-biliary structures. The patient should also avoid eating food items that produce excessive bowel gas like beans and other legumes. On the day of examination a patient should also avoid fizzy drinks. Examination of the ovaries, uterus and prostate require a full urinary bladder to serve as acoustic window for the evaluation of body structures when using trans-abdominal technique. However, this is not required for either the trans-vaginal or trans-rectal routes. A number of options are available for assessment of vascular structures in the abdomen and these include:

- Basic B-mode grey scale scan.
- Spectral Doppler ultrasound.
- Colour Doppler or colour flow imaging.
- Power Doppler ultrasound (Colour amplitude imaging).

More recently, elastography has also been added to the armamentarium of vascular ultrasound applications.
By way of explanation, a duplex Doppler US scanner can only display B-mode grey scale image and spectral velocity waveform tracing on the monitor. However, the newer generation colour Doppler machine is a triplex scanner because it can combine display of real-time grey-scale images with spectral velocity waveform and colour coded blood flow inside a vessel, contemporaneously on the image monitor. It should be noted that whereas colour Doppler imaging applications demonstrate direction of blood flow, power Doppler (colour amplitude) imaging, though more sensitive, only shows presence but not direction or velocity of blood flow.

**SONOGRAPHIC ANATOMY OF ABDOMINAL VASCULAR STRUCTURES**

Anatomy of the blood vessels is appreciated using B-mode grey-scale scan. The great vessels namely: abdominal aorta and inferior vena cava (IVC) are easy to visualize. The aorta in longitudinal scan lies to the left of the IVC. Proximally, its ventral branches are the coeliac trunk and superior mesenteric artery. Its lateral branches are the right and left renal arteries. Distally, the aorta gives off the inferior mesenteric artery as a ventral branch before it bifurcates into the right and left common iliac arteries at the level of the fourth lumbar vertebra. The common iliac arteries divide into internal and external iliac arteries. These arteries are accompanied by the corresponding common, external and internal iliac veins on both sides. The right and left testicular and ovarian arteries arise directly from the front of the aorta on either side, a short distance below the origins of the renal arteries.

Because of the higher number of muscular layers, the aortic wall appears more echogenic when compared to the IVC. This factor is also responsible for the rounded shape of the aorta in transverse scan vis-à-vis the IVC which usually appears oval shaped. The maximum diameter of the aorta in the mid-abdomen is 2.5 cm.

The IVC commences at the level of the fifth lumbar vertebra with the right and left common iliac veins as its major tributaries. As the IVC moves upwards in the abdomen, it receives blood from other tributaries including the right and left renal veins as well as the right and left hepatic veins. The right testicular and ovarian veins empty directly into the IVC. However, on the left side, these two veins empty into the left renal vein.

The hepatic and splenic arteries arise from the coeliac trunk. The splenic vein starts at the splenic hilum and moves to the right behind the pancreas where it receives the inferior mesenteric vein as a tributary; it then unites with the superior mesenteric vein in front of the IVC to form the portal vein. At the porta hepatis, the portal vein itself divides into right and left branches. The hepatic artery and common bile duct are usually seen running anterior and parallel to the portal vein in a longitudinal scan. During scanning, it is important to look at the aorta, IVC and other vessels in both longitudinal and transverse planes.
PHYSIOLOGY OF THE VASCULAR SYSTEM
For a successful Doppler examination of abdominal vessels, it is necessary to have a good knowledge of the pattern of blood flow in the major vessels namely: aorta and IVC as well as their branches and tributaries respectively. It is also important to know the pattern of blood flow in abdominal organs like the liver, kidneys, spleen, pancreas and bowel which have low resistance vascular beds. Blood flows from the descending thoracic aorta into the abdominal aorta where its speed is about 1 m/sec. In the renal arteries, blood flows at about 1 m/sec. In the hepatic artery, the speed of blood flow is about 0.5 m/sec.

The IVC receives major tributaries from the common iliac veins. As it ascends upwards, it receives tributaries from the renal veins and inside the liver, the hepatic veins empty into it.

TECHNIQUE OF SCANNING ARTERIES IN THE ABDOMEN

THE AORTA
To achieve proper visualization of the abdominal aorta, it is necessary to use optimum conditions for scanning. The aorta can be scanned using B-mode grey scale, colour Doppler imaging or power Doppler (colour amplitude imaging) applications. Usually, scanning in the longitudinal, transverse and coronal planes starts with grey scale imaging to look for evidence dilatation in aneurysm, stenosis, atheromatous plaques, calcifications, thrombosis and dissection.

The longitudinal scan helps to visualize a long segment of the aorta as well as its ventral branches namely: coeliac trunk, superior mesenteric artery (SMA) and inferior mesenteric artery (IMA). In transverse scan, the aorta is seen side by side with the IVC. Furthermore, in this view, the antero-posterior and transverse diameters of the aorta can be measured for evidence of dilatation in cases of aneurysm. The renal arteries can also be visualized in the transverse scan.

Coronal scan with the transducer in the flank may be required for better demonstration of the renal arteries as they branch out from the aorta; this view can also be used to demonstrate the aortic bifurcation and the common iliac arteries more clearly.
Imaging of the aorta is enhanced by colour Doppler imaging. Spectral Doppler is employed using the range gate to determine the pattern of velocity waveform and speed of blood flow. Spectral Doppler of the proximal aorta shows a monophasic systolic waveform with accompanying forward diastolic flow because it supplies blood to visceral organs which have a low resistance vascular bed (Fig. 7.1). In doubtful cases, power Doppler helps to resolve ambiguity about location of branches of the aorta, especially a small branch, like the inferior mesenteric artery. Because the aorta terminates in the iliac arteries which supply high resistance vascular beds in the pelvis and lower limb, the spectral Doppler of the distal aorta just above its bifurcation shows a triphasic waveform of high resistance with flow reversal during diastole.

Fig. 8.1: Spectral waveform of normal proximal abdominal aorta on duplex scanning showing systolic component with forward diastolic flow.

**COELIAC TRUNK**
The coeliac trunk is the first ventral branch of the abdominal aorta. It is demonstrated using a longitudinal scan where it is seen running a short distance downwards before subdividing into its own branches. When the celiac trunk has been identified by grey scale or colour Doppler, a range gate is placed inside the lumen to demonstrate spectral velocity waveform and obtain speed of flow.
SUPERIOR AND INFERIOR MESENTERIC ARTERIES
The superior mesenteric artery (SMA) is a ventral branch which takes its origin below the coeliac trunk before the branches of the aorta. The inferior mesenteric artery (IMA) is also a ventral branch which arises behind the third (horizontal) part of the duodenum and is best demonstrated by a longitudinal scan. The mesenteric arteries can be identified using B-mode grey scale scanning. On spectral Doppler after a meal, the SMA and IMA show the waveform of a low resistance vascular bed with biphasic waveform (Fig. 7.2). However, it is useful to employ colour Doppler flow and spectral Doppler to demonstrate evidence of stenosis especially in suspected cases of bowel ischaemia.

Fig. 8.2: Longitudinal view of normal SMA on duplex scanning with spectral Doppler display showing biphasic waveform of a low resistance vascular bed.

SPLENIC ARTERY
The splenic artery is the largest branch of the coeliac trunk and it lies along the upper border of the pancreas as it moves to the left towards the splenic hilum to supply the spleen. The body and tail of the pancreas are supplied by the artery, whereas the pancreatico-duodenal artery supplies the head of the pancreas. This artery is a branch of the gastroduodenal artery, which itself originates from the common hepatic artery. The splenic artery is better demonstrated by a transverse scan along its length as it runs across the abdomen. Proper visualization of arteries supplying the spleen and pancreas is aided by colour flow mapping from B-mode grey scale scanning and spectral Doppler velocity waveform display.
The splenic artery supplies visceral organs that have low resistance vascular bed hence its spectral velocity tracing shows a biphasic waveform due to high diastolic flow.

HEPATIC ARTERY
The hepatic artery (HA) and common bile duct (CBD) lie anterior to the portal vein (PV), but the HA and CBD are of smaller calibre when compared to the portal vein (PV). Under normal circumstances, flow in both the HA and PV are in the same direction into the liver. A combination of spectral and colour Doppler imaging would help to identify the HA and distinguish it from the CBD and PV. The liver has a low resistance vascular bed, hence spectral Doppler tracing of hepatic artery blood flow shows a biphasic waveform with high diastolic flow (Fig. 8.3).

![Fig. 8.3: Colour Doppler imaging of a normal hepatic artery. The spectral velocity tracing shows biphasic waveform of low resistance vascular bed.](image)

This helps to differentiate it from the portal vein which has a monophasic spectral Doppler velocity waveform (Fig. 8.4). Colour Doppler imaging would display identical colour signals in the PV and HA as blood flows into the liver. The CBD will not show any signals from both spectral and colour Doppler applications which readily appear when the range gate is placed inside the HA.
RENAL ARTERIES
The right and left renal arteries are lateral branches of the aorta and arise below the origin of the SMA. They are usually visualized on transverse scan but can also be demonstrated in the coronal scan. Grey scale imaging, spectral and colour Doppler are usually combined for optimum imaging of renal arteries and to measure the quantity of blood flow to the kidney especially in suspected stenosis. Because the renal arteries supply a low resistance vascular bed in the kidneys, spectral Doppler of these arteries shows biphasic waveform with high diastolic flow (Fig. 8.5).

Fig. 8.4: Duplex scanning showing monophasic spectral velocity waveform of normal portal vein.

Fig. 8.5: Colour Doppler imaging of normal renal artery with spectral analysis showing biphasic waveform due to low resistance vascular bed in the kidney.
TECHNIQUE OF SCANNING VEINS IN THE ABDOMEN

INFERIOR VENA CAVA AND ITS TRIBUTARIES
The right and left common iliac veins unite to form the IVC. These common iliac veins are difficult to visualize due to overlying bowel gas but their demonstration may be improved upon by using ultrasound probe to compress tissues in addition to changing the scanning position of the patient. Also due to bowel gas, the distal segment of the IVC is more difficult to scan than its proximal segment. As the IVC moves upwards in the mid abdomen, it receives tributaries from the right and left renal veins. Proximally in the abdomen, the IVC (Fig. 8.6) receives blood from the hepatic veins after which it crosses the diaphragm to empty into the right atrium. The proximal segment of the IVC is more readily visualized through the liver as it receives tributaries from the hepatic veins (Fig. 8.7).

The IVC is scanned in longitudinal and transverse planes. When not clearly visualized, scanning of the distal segment of the IVC can be improved upon by probe compression of the overlying tissues. At the level of the mid abdomen, the right renal vein is more clearly visualized by placing the probe in the right flank and doing a transverse scan (Fig. 8.8). On the other hand, the left renal vein, which is longer than the right, because it crosses the aorta anteriorly to reach the IVC; can be readily seen on transverse scan, using the anterior abdominal wall approach. The hepatic veins which are normally two in number namely: right and left hepatic veins, can be demonstrated using longitudinal scan. Valsalva manoeuvre helps to visualize the hepatic veins more clearly.

Fig. 8.6: Duplex scanning showing monophasic spectral velocity waveform of normal IVC in the mid abdomen.
The range gate is positioned inside the hepatic vein. Scanning of the IVC and its tributaries is commenced using grey scale imaging. This is followed by colour Doppler imaging to visualize flow. Spectral Doppler application is employed to assess the level of flow. The normal IVC shows a typical venous monophasic waveform in its spectral Doppler tracing. Post-Valsalva manoeuvre results in increased blood flow to the thoracic region because the intrathoracic pressure becomes reduced thereby producing improved blood flow in the IVC. Augmentation of flow in the IVC can be achieved by either squeezing of lower limb muscles or elevation of the lower limbs.

The right testicular and ovarian veins empty directly into the IVC. On the left side, because of the need to protect these tiny vessels from high pressure of the aorta, nature has made them to empty into the left renal vein.
THE PROSTATE
Trans-rectal ultrasound (TRUS) is the preferred approach for successful colour Doppler imaging of the prostate. Information obtained from colour flow of the prostate should be analyzed in conjunction with ultrasound appearances on B-mode grey scale scanning used as a complementary tool for results from other investigations such as prostate specific antigen (PSA) and biopsy. It is not always straightforward to distinguish between flow patterns in an inflammatory condition like prostatitis from those of tumours which have increased blood flow whether it is benign hyperplasia or carcinoma.

Where TRUS is not possible either due to non-availability of the required probe or inconvenience to the patient, then the trans-abdominal route can be used to image the prostate with good results in experienced hands.

THE UTERUS
Transvaginal ultrasound is the preferred method for vascular examination of the non-pregnant uterus. The uterus receives blood through the right and left uterine arteries, which are themselves branches of the internal iliac arteries. The non-gravid uterus has a high resistance vascular bed with low blood flow during diastole. Spectral Doppler of the uterine arteries shows a biphasic waveform with typical notch in the diastolic phase. Colour Doppler imaging is useful to show presence and direction of blood flow in the uterus. The pattern of uterine blood flow is different in pregnancy because as the placenta grows, it encroaches on the spiral arteries and this results in reduced resistance to blood flow making it become a low resistance vascular bed.

THE OVARY
The transvaginal route is desirable for detailed examination of blood vessels in the ovaries. The ovaries derive their own blood supply from two sources which are namely: ovarian arteries which are direct anterior branches of the abdominal aorta; each ovary is also supplied by the corresponding uterine artery. The pattern of blood flow in the ovaries as seen on spectral and colour Doppler imaging depend on the phase of the menstrual cycle; it is also affected by menopause.

During the proliferative (follicular) phase of the menstrual cycle as well as after menopause, there is low velocity of blood due to high impedance. Additionally, spectral Doppler would show peak systolic velocity. In these circumstances, colour Doppler flow might not adequately demonstrate the blood flow and power Doppler would be more useful. On the other hand, during the secretory (luteal phase) of the menstrual cycle, there is increased velocity of blood flow in the ovaries. The spectral Doppler velocity waveform shows increase in both the peak systolic velocity (PSV) and end diastolic velocity (EDV).
The mechanism of blood flow in the ovaries during different phases of the menstrual cycle and post menopause is as a result of anatomical and physiological changes due to hormonal alterations in the body. These in turn create complex blood flow patterns in the ovary especially during the secretory (luteal) phase; the details of which is beyond the scope of this book.

ULTRASOUND FINDINGS IN SOME ABDOMINAL VASCULAR CONDITIONS

ANEURYSM OF THE AORTA
The normal diameter of the abdominal aorta is usually not more than 2.5 cm. When the aortic diameter is between 2.5 - 3.0 cm it is said to be ectatic. Aortic diameter of more than 3.0 cm is indicative of aneurysm.

AORTIC DISSECTION
B-mode ultrasound in real time can be used to identify the presence of intimal flap aortic dissection. Importantly, colour Doppler can be used to determine the direction of blood flow in both the true and false lumens. Blood flow can be either in the normal caudad direction for both lumens or reversed in the false lumen giving cephalad flow. Consequently, blood flow to an affected kidney can become impaired if its renal artery is supplied with blood from reverse flow of a false lumen. Aortic dissection can arise from abdominal trauma or as a complication of radiological interventional procedures such as catheter arteriography.

PORTAL HYPERTENSION
When the liver sinusoids are damaged as a result of hepatocellular disease such as cirrhosis, this leads to reduction in the quantity of liver parenchyma that has normal function. Because of this, the portal vein dilates in response to increase in resistance to portal venous flow; thereby causing portal hypertension. Under normal circumstances, blood flow in the liver is hepatopetal. When the liver sinusoids are severely damaged in end-stage liver disease, blood flow becomes hepatofugal. This is a direct consequence of the blood in the hepatic artery that should normally enter hepatic sinusoids and flow into the hepatic veins being diverted directly to the portal vein through arteriovenous shunting or through vasa vasorum. In progressive portal hypertension, pressure in the portal vein builds up leading to formation of varices which serve as collateral channels for shunting of blood from the portal to systemic circulation; through some vessels like coronal veins, umbilical veins, left gastric and short gastric veins.
PORTAL VEIN THROMBOSIS
This condition may result from tumour invasion or clot formation. It may be asymptomatic or cause intestinal infarction or gastrointestinal haemorrhage. On B-mode grey scale ultrasound, early clot may be difficult to demonstrate because it is hypoechoic. However, when the thrombus matures, it is more echogenic in appearance. Colour Doppler will show loss of signals in the absence of blood flow in the portal vein due to thrombosis. In long-standing cases of portal vein thrombosis, collateral venous channels to the liver develop and these can be demonstrated with colour Doppler.

RENAL ARTERY STENOSIS
Doppler evaluation of the renal artery poses challenges which can be compounded by overlying bowel gas and obesity. It is preferable to use low frequency transducers in the range of 2.0-3.5 MHz designed for examination of the deep abdomen. Moreover it is not always possible to visualize the renal artery in its entire length on ultrasound, this being possible in about 70% of subjects undergoing Doppler scan. Even under good conditions and in the hands of an experienced operator, sensitivity of using direct visualization to assess the renal artery for stenosis is low and about 20%.

Causes of renal artery stenosis (RAS) are many and include: arteriosclerosis, fibromuscular dysplasia, arteritis, neurofibromatosis, thrombo-embolism and trauma. However, arteriosclerosis is by far the commonest cause of RAS; it is more frequently associated with the older age group since the incidence of atheroma increases with age; and it tends to be located near the origin of the vessel from the aorta. The next most common cause of RAS is fibromuscular dysplasia; it is encountered in younger persons; the stenosed segment is further away from the origin of the vessel at the aorta and closer to the kidney.

A combination of colour Doppler flow and spectral velocity waveform is essential for accurate diagnosis of RAS. An important role of ultrasound is in the follow-up of cases that have undergone angioplasty or surgical intervention. Features of RAS on colour Doppler scan include: narrowed renal artery lumen and turbulent flow with colour mosaic due to aliasing. The spectral velocity waveform of the artery may show reduction in velocity with increase in systolic rise time and spectral broadening. Within the intrarenal vessels, a classical “tardus parvus” tracing may be seen on spectral Doppler in RAS, which shows low amplitude waveform associated with prolonged systolic acceleration time.
RENAL VEIN THROMBOSIS
It is a disease that is more common in children and may result from dehydration leading to shock and nephrotic syndrome. In adults, the causes include: extension of renal carcinoma into the vein, compression by a tumour or retroperitoneal nodes, and extension of a thrombus from the inferior vena cava. On colour Doppler, there be absence of flow in the renal parenchyma or it occurs intermittently in peak systole. Also, a pattern of colour signals that alternate between red and blue in the renal arteries may be visualized. Classically, the spectral velocity waveform has an appearance of “W,” although this feature may also be present in some disease conditions like aortic incompetence and acute tubular necrosis.

DIFFERENTIAL DIAGNOSES OF SOME VASCULAR DISORDERS
1. AORTIC ANEURYSM
   ❖ Post stenotic dilatation in aortic stenosis.
   ❖ Markedly unfolded aorta in hypertension.
   ❖ Aortic incompetence.

2. PORTAL HYPERTENSION
   i. Hepatic Sinusoidal Cause:
      ❖ Cirrhosis.
   
   ii. Presinusoidal Causes:
      ❖ Portal vein thrombosis with umbilical sepsis.
      ❖ Portal vein obstruction by tumour.
      ❖ Granulomatous portal tract fibrosis from schistosomiasis.

   iii. Post Sinusoidal Causes:
      ❖ Hepatic vein thrombosis in Budd-Chiari syndrome.
      ❖ Constrictive pericarditis.
      ❖ Cardiac failure.

3. RENAL ARTERY STENOSIS
   ❖ Fibromuscular dysplasia.
   ❖ Arteritis.
   ❖ Thrombo-embolism.
   ❖ Extrinsic compression.
   ❖ Neurofibromatosis.
4. **RENAL VEIN THROMBOSIS**
   - Dehydration and shock.
   - Nephrotic syndrome.
   - Extension of renal tumour into the vein.
   - Compression of vein by a tumour or retroperitoneal nodes.
   - Extension of thrombus from IVC.

**Conclusion**

A good ultrasound Doppler examination of abdominal vessels can be achieved when the scan is performed under optimum conditions which include absence of interfering bowel gas and slim patients because excessive subcutaneous adipose tissue in fat patients interferes with transmission of sound waves and degrades the images. The choice of probe frequency is also important as deeply located vessels can only be properly demonstrated with low frequency transducers in the range of 2.0-3.5 MHz. It is necessary to view a vessel in both longitudinal and transverse scans when doing a B-mode grey scale examination. The angle of insonation of a vessel should ideally not be more than 60° to acquire adequate Doppler signals from blood flow in a vessel. A combination of spectral velocity waveform analysis and colour flow pattern is used to reach a diagnosis regarding the nature of disease in a vessel during a Doppler scan.
References

CHAPTER IX

GYNAECOLOGICAL ULTRASOUND
Tabari A.M

INTRODUCTION
Ultrasound diagnosis has become a major discipline in medicine. In women, the pelvis is a region where ultrasonography is of great value and importance. Pelvic viscera are traditionally imaged through a distended urinary bladder in what is called transabdominal sonography (TAS). The full bladder displaces the bowel loops upward away from the pelvic cavity, allowing the sound waves to pass through (sonic window) for optimum visualization of structures behind it. Transvaginal sonography (TVS) is the preferred technique for its better resolution of the uterus and ovaries than that obtained with conventional TAS (Table I). The two methods however, complement each other most often in complete evaluation of pelvic organs.

TABLE I: ADVANTAGES AND DISADVANTAGES OF TRANSVAGINAL SONOGRAPHY (TVS)

<table>
<thead>
<tr>
<th>ADVANTAGES</th>
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<tbody>
<tr>
<td>- Better resolution</td>
</tr>
<tr>
<td>- Full bladder is not necessary</td>
</tr>
<tr>
<td>- Good in difficult patients (such as in obese or in the presence of thick abdominal wall scar)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cannot view the entire pelvis, as such masses out of the range of pelvic cavity cannot be evaluated with highest degree of accuracy.</td>
</tr>
<tr>
<td>- It is contraindicated in patients with intact hymen.</td>
</tr>
</tbody>
</table>

Primary indications for pelvic sonography in women are tabulated in Table II. The structures imaged in the pelvis include the uterus, cervix, pouch of Douglas (cul-de-sac) and the adnexa. Other structures imaged along with these are the urinary bladder and the kidneys. Color Doppler ultrasound is employed to distinguish anechoic structures as either being cystic or vascular and also in the evaluation of ovarian torsion.
TABLE II: INDICATIONS FOR PELVIC SONOGRAPHY

- Evaluation of vaginal bleeding in early pregnancy
- Evaluation of pelvic pain
- Evaluation of pelvic mass
- Evaluation of pelvic infection
- Localisation of intrauterine device or foreign body
- Evaluation of abnormal uterine bleeding
- Evaluation of trauma

SONOGRAPHIC ANATOMY OF FEMALE PELVIC ORGANS

THE UTERUS
During TAS, the uterus is best visualized with distended urinary bladder. It can be imaged in several scanning planes. The uterus is the most centrally located and the most accessible organ, seen as a peer shaped structure behind the urinary bladder when viewed on longitudinal plane (Fig 9.1).

![Fig 9.1: A longitudinal ultrasound scan of normal postmenarchal uterus, the uterine body (Larger 2-way arrow) is larger than the cervix (Short 2-way arrow).](image)

The size and shape of the uterus varies according to the patient’s pubertal status, age and parity. It measures 8cm in length, 4cm in width and height in childbearing age. The multiparous uterus typically exceeds nulliparous size by 1cm in all directions (TABLE III). The normal echotexture of the uterine myometrium is smooth and homogenous in all ages, depicting echogenicity of low to medium.
TABLE III: VARIATION OF THE SIZE OF UTERUS WITH AGE

| Neonatal age: | Body larger than the cervix |
| Childhood: | Tubular shaped uterus (body smaller than the cervix) |
| Post pubertal: | Pear shaped uterus (body twice the cervix) |
| *Size: 8 x 4 x 4 cm |

* Multiparous uterus typically exceeds nulliparous uterus in size by 1cm in all directions.

The endometrium appears as central linear echogenicity, more prominent during menses. Its measurement and appearance varies with menstrual cycle (Table IV). It is thickest and brightest in the late secretory phase of the menstrual cycle (Fig 9.2).

TABLE IV: VARIATION OF ENDOMETRIAL THICKNESS WITH MENSTRUATION

<table>
<thead>
<tr>
<th>PHASE</th>
<th>DAY</th>
<th>APPEARANCE</th>
<th>*THICKNESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menstrual Phase</td>
<td>1 - 4 days</td>
<td>Thin interrupted echogenic line</td>
<td>1 - 4 mm</td>
</tr>
<tr>
<td>Early Proliferative Phase</td>
<td>5 - 9 days</td>
<td>Thin echogenic line</td>
<td>4 - 8 mm</td>
</tr>
<tr>
<td>Late Proliferative Phase</td>
<td>10 - 14 days</td>
<td>Triple line appearance</td>
<td>6 - 10 mm</td>
</tr>
<tr>
<td>Secretory Phase</td>
<td>15 - 28 days</td>
<td>Thick and echogenic</td>
<td>7 - 14 mm</td>
</tr>
</tbody>
</table>

*All measurements in true sagittal plane of the uterus, including both anterior and posterior walls of the endometrium.

The uterine cervix should have the same echogenicity and texture with the uterine myometrium, with hyperechoic central canal.
A HANDBOOK OF INTRODUCTORY ABDOMINAL ULTRASOUND FOR WEST AFRICA

FIG 9.2: A longitudinal ultrasound scan of normal postmenachal uterus, in secretory phase of the menstrual cycle showing the linear and echogenic central endometrial lining (black arrows).

THE ADNEXA
The adnexa consist of broad ligaments, fallopian tubes and ovaries. Under physiological conditions, fallopian tubes and broad ligaments cannot be visualized, while ovaries are seen in over 90% of cases by serial scans.

Because of their flexible attachment to uterus and lateral pelvic wall, the ovaries are often difficult to find in one position. They are generally oval shaped and hypoechoic when compared with the adjacent uterus. Its capsule and the central medullary portions are hyperechoic, while the cortical periphery is of decreased echogenicity due to the presence of multiple small follicles (Fig 9.3). Ovarian size is in the range of 3 x 2 x 1 x 2 cm after menarche.

FIG 9.3: A longitudinal ultrasound scan of the female pelvis, showing the normal right ovary (in between the cursors) with multiple small follicles.
CUL-DE-SAC
It is often referred to as the Pouch of Douglas (POD). It is an extension of the peritoneal cavity between the rectum and back wall of the uterus. The presence of small amount of fluid in the POD is normal in asymptomatic women throughout the menstrual cycle (Fig 8.4) and is thought to be due to transudate from ovarian and other pelvic organs serosa. The largest quantity of this physiological fluid is seen in the mid cycle during follicular rupture in the process of ovulation. This fluid is mostly clear fluid with no particles or strands.

FIG 9.4: A longitudinal ultrasound scan of the female pelvis, showing the urinary bladder, uterus and fluid outlining the POD (arrow).

SONOGRAPHIC PHYSIOLOGY OF THE MENSTRUAL CYCLE
Menstruation is that spontaneous, cyclical, bloody vaginal discharge that occurs monthly in women of childbearing age. It is initiated by hormones, the Follicle stimulating hormone (FSH) and Leutinising hormone (LH) released by the pituitary gland in the brain, thereby causing end organ changes, identifiable non-invasively by ultrasound in the ovaries (ovarian cycle) and uterus (uterine cycle).

THE OVARIAN CYCLE
**Follicular Phase:** Under the influence of pituitary hormones (FSH and LH) about 20 Graffian follicles visualized on ultrasound as small and peripherally sited anechoic cysts within each ovary starts to grow (Fig 3). Eventually, one of these follicles outgrowth the rest to become the dominant follicle, which can measure up to 2.5cm in diameter. The dominant follicle releases the oocytes in the process of ovulation around the mid cycle and then becomes the corpus luteum. The term *follicular cyst* refers to a dominant follicle which persists and failed to ovulate or a non-dominant follicle that retains fluid.
Luteal Phase: Fat globules are deposited in corpus luteum which continue to grow if pregnancy occurs. However, in the absence of pregnancy, the corpus luteum (which can reach up to 10cm in size) regresses gradually. It is identified as cystic structure (corpus luteum cyst), perhaps with irregular wall and internal echoes (haemorrhagic cyst). Follicular cyst, corpus luteum cyst, haemorrhagic cyst and theca luteum cyst (see below) are all referred to as physiological or functional cysts. They normally decrease in size or resolve on repeat ultrasound examination at different part of menstrual cycle, usually in 6 weeks time, when the patient is at a different phase of the menstrual cycle.

THE UTERINE CYCLE
Proliferative Phase: This corresponds to the follicular phase of the ovarian cycle and donates the process of cellular proliferation and glandular enlargement in the endometrial lining of the uterine cavity, under the influence of oestrogen released by the growing follicles.

Secretory Phase: Soon after ovulation, the endometrium continue to grow under the influence of progesterone produced by the corpus luteum in the ovary (Table IV).

SONOGRAPHIC TECHNIQUE OF DEMONSTRATING THE PELVIC ORGANS
The indications, contraindications and the methods used in the sonographic evaluation of the female pelvis were outlined in Tables I & II. Transperineal sonography introduced in 1986 is often added for completion (Table V).

TRANSABDOMINAL SCAN (TAS)
- Fully distended urinary bladder needed, such as by giving oral water load 1-3hrs prior to the examination.
- Probe: 3-5 MHz, Sector transducer after liberal application of coupling gel.
- Technique: Direct coronal scanning technique with the patient in supine position.
- The uterus is centrally located and the most accessible organ for ultrasound evaluation, identified posterior to the distended urinary bladder (Fig 9.4).
- The ovaries are searched for in the adnexal regions lateral to the uterus, anterior the iliac vessels (NB: The location of the ovaries is extremely variable in normal patients, because of their flexible attachment to the uterus and lateral pelvic wall).
- The cul-de-sac (Fig 9.4), visible in longitudinal plane between the back wall of the uterus anteriorly and the echogenic anterior surface of the rectum posteriorly. It is well visualized in both longitudinal and transverse planes when fluid filled.
TRANSVAGINAL SCAN (TVS)

- Full bladder not necessary.
- Probe: 5.0 – 7.5 MHz transducer covered with condom.
- Technique: The probe is inserted within the vagina and manipulated around the cervical lips and fornices for detailed evaluation of structures of interest. 3 imaging planes were available:
  - Sagittal Plane: Identifies uterus in the long axis. Angulation of the transducer to the right and left of the midline enables the ovaries and iliac vessels to be visualized.
  - Semicoronal plane: Obtained by turning the probe 90° counterclockwise (counterclockwise maintains standard right-to-left orientation). Adnexal structures are depicted.
  - Semiaxial Plane:
    - Probe turned as in semicoronal but the beam is directed anteriorly,
    - When directed posteriorly, image of the cul-de-sac is obtained while withdrawing the probe from the vaginal fornices into the mid-vagina.

TRANSFERINEAL SCAN

TABLE V: INDICATIONS FOR TRANSFERINEAL SONOGRAPHY

- Diagnosis of incompetent cervix during pregnancy.
- In suspected placenta praevia, for proper delineation of the margin of the placenta in relation to internal os.
- Demonstration of early intrauterine pregnancy in a retroflexed uterus, in the absence of transvaginal approach.
- Evaluation of urinary stress incontinence.
- Evaluation of vaginal atresia (Performed with a stand-off pad).
- Useful alternative to TVS in young girls who are still virgins.

ULTRASOUND IMAGING OF PELVIC PATHOLOGY

CONGENITAL CONDITIONS

Incomplete fusion of Mullerian ducts results in duplication anomaly of the uterus (Table VI). It occurs in 0.5% of women and it is usually asymptomatic, but often associated with dysmenorrhoea, repeated spontaneous abortion, infertility and pregnancy complications, such as obstructed labour (when a duplicated horn presents as a pelvic mass) and renal anomalies, especially renal agenesis.
TABLE VI: CONGENITAL UTERINE ABNORMALITIES

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<tbody>
<tr>
<td>1.</td>
<td>Unicornuate Uterus (Single horn Uterus).</td>
</tr>
<tr>
<td>2.</td>
<td>Bicornuate Uterus (Two horns uterus: Bicornis Unicollis = 2 horns + 1 cervix; Bicornis Unicollis = 2 horns + 2 cervixes).</td>
</tr>
<tr>
<td>3.</td>
<td>Arcuate Uterus (a mild form of bicornuate).</td>
</tr>
<tr>
<td>4.</td>
<td>Septate Uterus (a fibrous septum separates 2 horns, associated with smooth external contour).</td>
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The diagnosis of uterine abnormality is based on clear visualization of the uterine cavity echo (endometrial line) in transverse section, best performed in the secretory phase of the menstrual cycle, when the endometrium is at its thickest and highly echogenic.

TAS approach identifies the degree of separation of the uterine horns and defines the external contour of the uterus, while TVS approach demonstrates the endometrial stripes better in secretory phase.

ACQUIRED CONDITIONS

The acquired pathologic conditions of the pelvis are systematically discussed under the following headings:

- Adnexal lesions,
  - Cystic lesions
  - Complex lesions
  - Solid lesions
- Uterine lesions,
  - Abnormal myometrium
  - Abnormal endometrium
  - Abnormal cervix
- Fallopian tube lesions
- Specific lesions of the pelvis of sonographic importance: Ectopic pregnancy, Ovarian torsion, Molar pregnancy, Pelvic inflammatory disease and Infertility.

ADNEXAL LESIONS

Patients with adnexal lesions often presents with lower abdominal pain, vaginal discharge, suspected or palpable mass and abnormal bleeding per vaginum. Commonly encountered lesions in the adnexa could be solid, cystic or complex (mixed solid and cystic). Generally, functional ovarian cysts and benign neoplasms comprise most of the adnexal lesions in women of reproductive age group, while in older women malignant lesions predominate.
The ability to demonstrate the ovary separate from adnexal lesions exclude ovarian origin of that lesion. Therefore, while scanning the pelvis, efforts should be geared towards demonstrating the ovary separate from other adnexal structures, using the uterus as a central landmark. Applying a gentle pressure between an adnexal mass and the uterus may further elucidate the origin of the mass. For instance, in differentiating a subserous and pedunculated fibroids (that moves along with the uterus) from an adnexal mass which moves away from the uterus on application of such pressure.

**CYSTIC ADNEXAL LESIONS**

A. **SIMPLE/BENIGN CYSTS**:  
- Ovarian  
- Adnexal

Characteristically, simple cysts have the following features:
- Completely anechoic (no septations or solid elements within it)
- It shows good through transmission of sound waves with distal acoustic enhancement
- Thin and smooth wall.

**SIMPLE OVARIAN CYSTS:**

*Normal simple ovarian cysts*: These are the normal follicles (growing and matured) and the corpus luteum.
- **Characteristics**: Size, usually 3cm and below in diameter,  
- **Consistency**: Unilocular (Simple cyst),  
- **Management**: Repeat scan after 6 weeks (when the patient must have been in a different cycle) to determine regression.

**Functional/Physiologic cysts**: The commonest cause of ovarian enlargement in young women. Cysts in this group includes, follicular cyst, Corpus luteum cyst and haemorrhagic cyst.

**Follicular and Corpus luteum cysts**:
- **Size**: 2 – 10cm and usually unilateral,  
- **Consistency**: Unilocular (Simple cyst),  
- **Management**: Repeat scan after 6 weeks (when the patient must have been in a different cycle) to determine regression.

**Haemorrhagic cysts**:
- **Size**: 2 – 10cm  
- **Consistency**: Complex (see below)  
- **Management**: Repeat scan after 6 weeks to determine regression or change in internal characteristics.
iii. **Benign ovarian neoplasm**
   - Size: Typically >6cm,
   - Consistency: Unilocular (characteristic of simple cyst),
   - Management: Increase in size on repeat scan suggest benign neoplasm e.g cystadenoma.

iv. **Theca luteal cyst**
   - Size: Large and bilateral,
   - Consistency: Multiloculated,
   - Aetiology: Due to hyperstimulation of the ovary, such as in multiple pregnancy, gestational trophoblastic disease and the use of infertility drugs.

**SIMPLE ADNEXAL CYSTS**

i. **Paraovarian cyst (Cyst of the broad ligament)**
   - Size: Variable,
   - Consistency: Unilocular (characteristic of simple cyst),
   - Management: Does not change with the menstrual cycle on follow up scan.

ii. **Peritoneal inclusion cyst**
   - Size: Variable,
   - Consistency: Simple cyst,
   - Aetiology: History of prior surgery is almost always positive (Differential diagnosis include, urinoma, seroma and lymphocele).

iii. **Hydrosalpinx**
   - Size: Variable,
   - Consistency: Simple cyst (Hydrosalpinx), Pyosalpinx (pus filled tube), Haematosalpinx (blood filled tube) – The last two often contain internal echoes within the fluid.
   - Shape: Tubular, serpiginous and aperistaltic.

**COMPLEX ADNEXAL LESIONS**
Complexity in adnexal lesions signifies mixture of both solid and cystic elements in a tumour. The division therefore is that of complex-predominantly cystic and complex-predominantly solid.
COMPLEX-PREDOMINANTLY CYSTIC ADNEXAL LESIONS:
- Characteristics: Predominantly cystic mass containing internal echoes, such as septa, solid tissue or other echogenic materials.
- Examples:
  - Ovarian cystadenoma,
  - Dermoid cyst,
  - Tubo-ovarian abscess,
  - Endometrioma,
  - Haemorrhagic ovarian cyst.

i. **Ovarian cystadenoma (Serous or Mucinous)**
   - Large ovarian mass
   - Internal septa (echogenic and linear)

ii. **Dermoid cyst (Matured cystic teratoma – MCT)**
   - The commonest childhood ovarian tumour,
   - Mainly unilateral (10 – 15% bilateral),
   - Ultrasound:
     - It has a characteristic echogenic mural nodule (dermoid plug),
     - Focal calcification with posterior shadowings may represent tooth elements and obescures deeper portions of the mass (The tip of Iceberg sign)- Fig 8.5.
     - Fluid-fluid level due to the presence of fatty material (sebum) layered on serous fluid.

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**FIG 9.5:** A longitudinal ultrasound scan of the female pelvis, showing the urinary bladder, uterus and a cystic ovarian mass with a focal echogenic nodule casting distal acoustic shadow (surgically confirmed dermoid).
Management: Dermoids are removed surgically to avoid possible complication of rupture or torsion of the ovary. Plain radiography, CT and MRI are complimentary in the evaluation of Dermoids.

iii. **Endometriosis**
- This refers to the ectopic presence of endometrial tissue outside the uterus, with the ovaries as the commonest site of implantation.
- The localized form of the disease creates *endometrioma*.
- Ultrasound:
  - Cyst with diffuse low amplitude, internal echoes.
- Differential diagnosis:
  - Functional ovarian cyst, abscess.
- *Adenomyosis* is the term used when nests of endometrial tissue are located within the myometrium (see below), while *catamenial pneumothorax* is used when there is endometrial tissue in the pleural surface associated with secondary pneumothorax (Rt sided mainly) corresponding to the time of menstrual period.

iv. **Tubo-ovarian abscess (See below)**
- A spectrum within pelvic inflammatory disease (PID) of an abscess involving the tube and ovary.

v. **Haemorrhagic ovarian cyst (see above).**

**COMPLEX-PREDOMINANTLY SOLID ADNEXAL LESIONS:**
- Characteristics: Adnexal lesion exhibiting predominantly solid and partly cystic appearance.
- Examples:
  - All those listed above in complex-predominantly cystic section,
  - Endometroid tumour.

i. **Endometroid tumour:**
- Approximately 80% of ovarian endometroid tumours are malignant and bilateral in 28% of cases.
- Ultrasound:
  - Presents as cystic mass containing papillary projections or as a predominantly solid mass with cystic portion.
SOLID ANEXAL LESIONS

Uterine fibroids (leiomyomas) are the commonest tumour of the pelvic cavity and when presents subserously, especially if pedunculated can present as an adnexal mass lesion. Solid ovarian tumours, even though relatively uncommon when compared with their cystic counterparts can also presents as such and they typically arise from either adenocarcinoma or other less differentiated solid ovarian tumours such as Fibroma, Brenner tumour and Thecomas.

Metastasis to the ovaries commonly from the breast and gastrointestinal tract are not uncommon. They presents as bilateral solid masses.

Meig’s syndrome is when there is triad of ascites, pleural effusion and solid ovarian tumour due to fibroma. Removal of the fibroma results in resolution of the fluid collection.

Struma ovarii occurs when a thyroid tissue is found in the ovary. It accounts for approximately 3% of all mature teratoma and it is thus, a histological diagnosis.

Krukenberg’s tumour is an ovarian tumour secondary to metastasis from gastrointestinal (mainly stomach) primary.

UTERINE LESIONS

Acquired abnormalities of the uterine cavity and its lining, myometrium and the uterine cervix are frequently encountered during pelvic sonography. Mullerian ducts anomaly and foreign bodies (eg due to IUCD) are other rare incidental findings on pelvic sonography.

ABNORMAL MYOMETRIUM

i. Uterine Fibroids (Leiomyoma)
   - The most common tumour of the uterus.
   - It is described as a benign tumour of smooth muscle arising from the uterus.
   - Its clinical significance depends on its size and location:
     - Size: Varies greatly in size and are often multiple.
     - Location: Fibroids are characterized based on their location, thus:
       - Submucosal:
         - Projecting into the uterine cavity
         - Most symptomatic, causing irregular or heavy bleeding, infertility, etc.
       - Intramural:
         - Most commonly encountered.
       - Subserous:
         - Projects from the serosal surface of the uterus and distorts uterine margin.
o Pedunculated:
  - May mimic adnexal mass and may have a stalk connecting it with the main uterus

o Cervical:
  - Visualised in the uterine cervix,
  - Not as common as those listed above.

- Ultrasound characteristic:
  - **Appearance:** Commonly presents as a well defined, discrete multiple masses or simply cause diffuse uterine enlargement.
  - **Echogenicity:** Mainly hypoechoic, occasionally may be iso or hyperechoic.
  - **Calcification:** Fibroids are the most common cause of dense echoes (calcifications) in the uterus and appear as rim calcification or clumps of calcification.
  - **Cystic degeneration:** This produces an anechoic space within a fibroid with through transmission.

ii. **Adenomyosis**
- This applies to ectopic endometrial invasion of the myometrium.
- Patients often presents with painful and heavy menses.
- Ultrasound: Diagnosis on ultrasound is difficult as the uterus is diffusely enlarged without a focal mass.
- Focal adenomyosis also occur. The differential diagnosis is with fibroids which are well circumscribed, while focal adenomyosis are ill-defined and may have lacunae. When in doubt, MRI is useful in distinguishing these two possibilities.

**ABNORMAL ENDOMETRIUM**

i. **Thickened endometrium**
- Normal endometrial thickness in women of reproductive age group has been discussed above (Table IV).
- In asymptomatic post menopausal women not on hormonal replacement therapy (HRT) should be less than 5mm. An endometrial thickness greater than 10mm in post menopausal women is considered as abnormal.
Ultrasound:

- The triad of Carcinoma, Hyperplasia and Polyps affects the endometrium more as the menopause approaches.
- Preserved endometrial-myometrial interface differentiates hyperplasia and polyps from endometrial carcinoma in which it is lost.
- Sonohysterography (a procedure where a saline is injected into the endometrial cavity via a catheter under ultrasound control) often better characterizes different causes of endometrial thickening when in doubt.

ii. Endometrial carcinoma.
Vaginal bleeding is the most common presenting symptom in post menopausal women with endometrial carcinoma.

Ultrasound:
- Thickened endometrium,
- Loss of endometrial – myometrial interface,
MRI is more accurate than ultrasound in staging of endometrial carcinoma.

ABNORMAL UTERINE CERVIX
i. Cervical cancer.
- The most common gynaecologic malignancy in women of reproductive age group.
- Ultrasound:
  - Solid cervical mass of varying echogenicity (Fig 8.6).
  - Irregular outline most often.
  - Ultrasound is useful in staging cervical cancer where MRI is unavailable.
- Differential diagnosis of cervical mass: Cervical fibroid (solid), Nabothian cyst (cystic), Ectopic pregnancy, Cervical polyp.

![FIG 9.6: A longitudinal ultrasound scan showing a solid utrine cervix mass of moderate echogenicity (in between arrows) due to cervical carcinoma. Open curved arrow = uterine fundus.](image)
FALLOPIAN TUBE ABNORMALITY
In the sonographic diagnosis of tubal lesions, efforts should be directed in identifying the ovaries and the uterus separate from the suspected tubal lesions. Based on its consistency, lesion of the fallopian tube could be cystic, solid or complex:

CYSTIC TUBAL LESIONS (Commonest)
- Hydrosalpinx
- Pyosalpinx
- Ectopic pregnancy.

SOLID/COMPLEX TUBAL LESIONS
- Tubo-ovarian abscess
- Carcinoma of the fallopian tube (rare)
- Ectopic pregnancy.

SPECIFIC LESIONS OF THE PELVIS OF SONOGRAPHIC IMPORTANCE
- Ectopic pregnancy
- Ovarian torsion
- Pelvic inflammatory disease (PID)
- Molar pregnancy
- Infertility.

ECTOPIC PREGNANCY
1. Definition: Implantation of fertilized ovum outside the uterine cavity
2. Sites of implantation: Fallopian tube (commonest site), Ovary, Cervix and abdomen
3. Risk factors for ectopic pregnancy:
   - Prior history of PID,
   - Previous tubal surgery,
   - Assisted reproductive techniques,
   - Intrauterine Contraceptive Device (IUCD) use and
   - Prior ectopic pregnancy.
4. Clinical symptoms:
   - Typical symptoms:
     - Delayed menses
     - Irregular vaginal bleeding
     - Abdominal/pelvic pain.
   - Atypical symptoms (common): Mimics all kind of diseases, such as appendicitis, PID, Urinary tract infection (UTI) e.t.c
5. Diagnosis:
   i. Ultrasound
   ii. Non-Ultrasound

6. Ultrasound:
   i. Intrauterine signs
   ii. Adnexal signs
   - Intrauterine Ultrasound signs:
     - Empty uterine cavity +/- endometrial thickening
     - Pseudogestational sac (due to decidual cast or haemorrhage), mainly centrally located with poorly defined margin.
     - There may be concurrent intrauterine pregnancy, the so-called heterotopic pregnancy.
   - Adnexal Ultrasound signs:
     - Gestational sac with embryonic echo and positive cardiac activity clinches the diagnosis.
     - Gestational sac with embryonic echo with no cardiac activity is also diagnostic.
     - Gestational sac with embryonic echo +/- collection in the pouch of Douglas or Paracolic gutter.
     - Non specific adnexal tumour +/- Fluid in the POD or Paracolic gutter.

7. Non ultrasound Signs:
   - Serum Beta HCG (Human Chorionic Gonadotropin) level (More sensitive)
   - Urinary Beta HCG levels (Positive in 40 -60% of ectopic pregnancies).

MIMICS OF ECTOPIC PREGNANCY ON ULTRASOUND
   - Corpus Luteum
   - Ovarian Follicle
   - Small bowel loops
   - Hydrosalpinx
TREATMENT OF ECTOPIC PREGNANCY

- Haemodynamically stable patients: Medical treatment with systemic or local methotrexate or other feticide agents, in an attempt to preserve fertility.
- Haemodynamically non-stable patients: Emergency laparotomy or laparoscopic surgery.

OVARIAN TORSION

1. Definition: Complete or Incomplete twisting of the ovarian pedicle, mostly on the right side.
2. Risk factors for the development of torsion:
   - Ovarian mass
   - Prepubertal female
3. Clinical symptoms:
   - Acute onset lower abdominal pain.
   - Palpable mass may be present.

   Ultrasound Diagnosis:
   - Enlarged ovary with multiple peripheral cortical follicles.
   - Free fluid is often present in the pelvic cavity.
   - On Colour Doppler ultrasound, complete torsion show absent of flow in ovarian vessels, while in partial or early onset torsion flow is preserved.

MIMICS OF TORSION, CLINICALLY AND AT IMAGING:
- Ectopic Pregnancy
- Acute Appendicitis
- Pelvic Inflammatory Disease
- Haemorrhagic Ovarian Cyst
- Endometriosis

TREATMENT OF OVARIAN TORSION

- Laparoscopic untwisting in viable and incomplete torsion.
- Adnexectomy is performed when the ovary is not viable on Doppler and gross examinations.
MOLAR PREGNANCY

- Definition: A form of gestational trophoblastic disease characterized with hydrophilic, swollen and avascular villi and proliferation of trophoblasts.

- Ultrasound diagnosis:
  - Bulky uterus,
  - Highly echogenic placental tissue interspersed with bizarre fluid filled vesicles, giving the so-called Snow storm appearance (Fig 9.7).
  - In complete mole, no embryo or amniotic membrane is seen.
  - Partial mole presents as a focal lesion in the presence of embryonic or fetal elements.

![Figure 9.7](image)

FIG 9.7: Cross section of the uterus, showing the snow storm pattern of Molar pregnancy

PELVIC INFLAMMATORY DISEASE (PID)

1. Definition: PID is an inflammatory condition involving to varying degrees the fallopian tubes, ovaries and surrounding tissues.

2. Causes:
   - Ascending infection from the vagina and uterus.
   - Direct spread from adjacent inflammatory process such as diverticulitis, Appendicitis or inflammatory bowel disease.

3. Ultrasound diagnosis: There are wide spectrums of findings involving single, multiple or all of the pelvic organs. Thus:
   - Uterus: Mild uterine enlargement.
   - Endometrium: Endometrial thickening or fluid within the endometrial cavity (endometritis).
   - Cul-de-sac: Fluid in the POD (may be particulate fluid).
Fallopian tubes: Chronic Infection presents as an uncomplicated fluid filled tubular structure with a thin wall (Hydrosalpinx). Acute infection manifests as thickened, tender, nodular and hyperaemic tube wall. There may be internal debris (Pyosalpinx).

Ovary: Present as a complex adnexal Tubo-ovarian mass (a heterogenous pelvic mass known as Tubo-ovarian abscess – TOA).

INFERTILITY
Definition: Failure to conceive a desired pregnancy after twelve months of uninterrupted intercourse.

Causes / Ultrasound evaluation:
- **Uterine factors:**
  - Congenital uterine anomalies.
  - Endometrial Polyp: Appear as diffuse or focal thickening of the endometrium. Best demonstrated on sonohysterography during secretory or periovulatory phase of the menstrual cycle.
  - Thin Endometrium: Thickening of the endometrium below 7mm is considered as a reliable sign of suboptimal implantation potential.
  - Endometrial blood flow: The presence of subendometrial blood flow on Doppler evaluation is indicative of good endometrium.
  - Endometritis.
  - Submucous fibroids.
  - Adenomyosis.
- **Ovarian factors:**
  1. Polycytic Ovarian Syndrome (PCOS)
     - Characteristics: Infertility, Oligomenorrhoea, Hirsutism and Obesity.
     - Aetiology: Tonic hypersecretion of LH during follicular phase of the menstrual cycle, associated with theca cells and stromal hyperplasia and consequent androgen overproduction.
     - Ultrasound findings: Enlarged ovaries with multiple, small and peripherally sited cysts (Fig 9.8). Increased stromal echogenicity. In 30% of cases the ovarian volumes are normal.
FIG 9.8: Cross section of an enlarged right ovary with multiple peripherally sited small cysts in PCOS. One of the cyst measures 8mm in diameter (in between cursors). Similar finding was found in the left ovary.

2. Luteinised Unruptured Follicle Syndrome (LUF)
   - Definition: Failure to release ovum at ovulation, despite regular menses and normal cyclical hormonal profile.
   - Aetiology: Possibly due to impaired mid-cycle LH surge and absence of pre-ovulatory progesterone rise.
   - Frequency of occurrence: 6 – 47 %.
   - Ultrasound findings: On serial scanning, during the period of expected ovulation, the follicle remain the same size and maintain a tense appearance. On further scanning, there will be progressive accumulation of strong echoes in the unruptured follicle (the process of luteinisation).

   - Tubal factors: Tubal occlusion (with or without hydrosalpinx) or damage as a result of previous or active inflammatory process (PID).
References


INTRODUCTION

Obstetric ultrasonography is the most commonly requested ultrasonographic study likened to chest radiography in the conventional radiography. The gestational period is filled with expectation of the successful birthing of “one cell that will eventually become a human being”. Obstetric ultrasonography is therefore poised to help answer the several questions of the expectant mother.

Obstetric ultrasonography is known to have the capability of defining the status of the gestation - intra-uterine or extra-uterine; single or multiple and if multiple, the type of multiple gestation- determined by the chorionicity and amnionicity; it has the capability of determining the gestational age and weight of the foetus and generally assessing the milieu of the foetus and maternal uterine and adnexal anatomy.

Dependability on ultrasonography in obstetric care is on the increase, the figures quoted as 48% to 68%, over a 15 year period in a USA study. Given this upward trend therefore, it can be estimated that even higher percentages of pregnant women undergo ultrasound studies in the USA and higher still in countries where it is considered part of routine antenatal care.

Advancing technology has brought ultrasonography into the hands of practically every one, be they quacks or specialists, with their various reasons for using the ultrasound equipment, ranging from easy means of making money to the consciencious and excellent contribution to expert health care delivery.

Available and affordable as it is however, it is critically only useful in the well trained, skillful and experienced hands for optimum evaluation of the maternal and foetal features. The reward for the successful performance of obstetric ultrasonography is unquantifiable, ranging from the immeasurable joy of the individual family to the contribution to the reduction in maternal and child morbidity and mortality in any community.
It is therefore imperative that sonologists and sonographers performing obstetric ultrasonography should have completed appropriate training which would have adequately equipped them for expertise in obstetric sonography. The course content of such an academic program should include basic physics of ultrasound, the equipment, gross, cross-sectional and sonographic anatomy of the female pelvis in non-pregnant and pregnant states, physiology of pregnancy indications of obstetric ultrasonography, safety of ultrasound in pregnancy, medical records keeping, medical ethics, professional conduct, be appropriately certified in proficiency and be registered with the appropriate Board. The knowledge of high risk pregnancies and how to detect pointers to them at ultrasonography is a must. Continuous Professional Development should be mandatory.

Regular inspection and accreditation of ultrasound centres will ensure compliance with the minimum standards and guidelines of practice. Approved protocols must be followed in detail.

Knowledge of common pitfalls must also be ingrained in the ultrasound practitioners.

In choosing equipment for use in obstetric ultrasonography, the ultrasound practitioner must clearly understand that the transducer frequency is a trade-off between beam penetration and resolution. Higher frequency transducers are most useful in achieving high resolution scans and lower frequency transducers are useful when increased penetration of the sound beam is necessary, such that 3-5MHz transducer will therefore provide adequate resolution with adequate depth penetration in all but the very obese patient in who lower frequency (2MHz) transducer will be required. Very early gestation will require higher frequency transducer 4-7MHz for transabdominal studies or 5-10MHz transducer for transvaginal studies.

When indicated, Doppler ultrasonography, three-and-four dimensional ultrasonography are also useful for optimizing the image acquisition.

Technique of the study, special features and all findings must be completely documented, interpreted and clearly written out in the Report for quality assurance, accreditation and medico-legal issues.

This chapter will be structured as outlined below with the aim of giving information on all the above topical issues in the hope of guiding and aiding the ultrasound practitioners in safe and best practice, the Patient being the primary concern.
Outline
- Basic anatomy (gross and sonographic) of the female pelvis and anatomic changes in the pelvis of a pregnant woman, including brief relevant physiology of the pregnancy.
- Protocol for the first, second and third trimesters ultrasound
- Sonography in the first trimester
- Normal findings in sonography in the first trimester
- Sonography in the second and third trimester - Gestational age assessment etc
- Sonography in the second and third trimester - abnormal
- Fetal Anomalies, Chromosomal and their markers; structural
- Placenta, amniotic fluid, the cervix
- Multiple pregnancies
- Biophysical profile
- Common pitfalls
- Medical ethics/ Professional conduct in Obstetric Ultrasonography

Anatomy of the pelvis in the non-pregnant and pregnant states
The knowledge of the pelvic anatomy in the non-pregnant and pregnant states; and the physiology of pregnancy are prerequisites to any diagnostic approach to obstetric ultrasonography.

The pelvis is the area between the trunk and lower limbs. It is made up of bony pelvis and soft tissue structures like the uterus, fallopian tubes, ovaries, the contents of the adnexae and other structures like the small intestines, bladder, sigmoid colon and rectum. Vascular structures, muscles and fasciae also make up part of the pelvic content.

Components of the bony pelvis- two innominate bone fusion of
- ilium
- ischium
- pubis

The three of which form the acetabulum
- The sacrum and coccyx are the distal spinal structures which make up the pelvis posteriorly, joining the ilium, ischium and pubis to form the pelvic cavity.

The pelvic bones therefore attach the lower limb to axial skeleton; transmit weight of the upper body and supports viscera. The levator ani, pyriforms and coccygeus muscle form the pelvic diaphragm or floor.
The pelvis is divided at the level of the pelvic brim into the **false** and the **true Pelvis**

![Diagram of the pelvis](image)

**Fig 10.1**: Schematic diagram of the pelvis (true and false) in the frontal view (A) and the Lateral view of the content of true pelvis (B) and sonographic correlation (C)

*Courtesy: Frank Netter’s Atlas of Anatomy (A & B)*

The False Pelvis is above the pelvic brim and is made up of both iliac fossae, which is attachment for muscles and ligaments from trunk. It contains abdominal organs.

The True pelvis contains:

- **The urinary bladder** - a thick muscular organ located behind the symphysis pubis. Its base where the ureters insert, is called the trigone. On normal transducer orientation, it is visualized on the right side of the monitor on sagittal scan Fig 10.1C. On transverse scan, it is square shaped, anterior to the uterus. The bladder has an echogenic wall of about 3mm thickness when distended with anechoic urine.

- **The vagina** - The vagina is a fibromuscular structure which extends from the vulva to the uterus, terminating at the fornices, its posterior wall being longer than its anterior wall. Its axis is usually directed towards the sacrum, which is related to it posteriorly and the bladder relates to it anteriorly. It is visible as a characteristic echogenic stripe i.e. linear echogenicity (Black arrows in Fig 10.1C), its longer posterior wall can be seen to extend behind and above the uterine cervix.

- **The uterus** - The uterus is a pear shaped solid muscular organ, the size of which varies with age, parity (the multiparous’ being larger than the nulliparous’). In parous women, the body of the uterus (corpus uteri) is twice the length of the cervix which is the reverse in both premenarchial and postmenopausal females. Its anterior and posterior relations are urinary bladder and sigmoid colon respectively while bilaterally are the uterine adnexae comprising of the Broad Ligament, vessels, tubo-ovarian complex and the ovaries. Anteriorly and posteriorly are potential spaces named Vesico-uterine pouch and Pouch of Douglas (Cul de Sac) respectively. The uterus is made of three parts- fundus, body or corpus uterii and the cervix; each surrounded by three layers -the serous membrane, myometrium, and endometrium.
In the pelvis, its position can be anteverted i.e. an anterior tilt from the cervix, retroverted i.e. a posterior tilt from the vaginal vault. It can also fold on its self anteriorly or posteriorly termed ANTEFLEXION and RETROFLEXION respectively. Though the uterus lies in the mid-line, it may also lie obliquely to the left or to the right. Sonographically, using a normally oriented transducer, it appears as a hypoechoic low level teardrop on the sagittal scan with the anteriorly located bladder on the right of the screen. Centrally, along its sagittal plane is an echogenic endometrial plate which is the apposed anterior and posterior layers of the endometrium. Its position can best be demonstrated sonographically with the transvaginal scan. Its appearance changes with the physiological state of the body- being thin in the proliferative phase of the menstrual cycle and thickened in the secretory phase. Post-implantation of the fertilized ovum, this thickness increases remarkably, an appearance termed Decidual Reaction. In the uterus’ normal anteflexed state, the fundus is to the Rt of the screen while the Cervix is to the left.

Bilaterally, from its superomedial margins (the cornua), extend the 8-10cm long thin fallopian tubes which lie within the broad ligament, extending to the ovaries. Each is composed of four parts- interstitial, isthmus, ampulla and infundibulum. When not dilated, they are not visualized on sonography.

The Ovaries - Ovaries have variable positions in relation to the uterus i.e in relation to the fundus, they could be superior, inferior or adjacent to the fundus (cornu). They may also be seen in the Cul-de-sac, these positions being determined by parity, laxity of ligaments, uterine size and position. They are oval in shape, measuring 2-5cm x 2-3cm x 1.5-3cm in the longitudinal, antero-posterior and transverse dimensions respectively. Sectional anatomy of the ovary demonstrates two layers -the outer cortex and the inner medulla. Vessels enter and exit the ovary through the medulla while the cortex contains follicles at various stages of development. The surface of the ovary is covered by specialized peritoneum called germinal epithelium. Sonographically, the medulla is moderately hyperechoic while the cortex is hypoechoic, with anechoic follicles of varying sizes outlining the cortical margin. The ovaries are support by a number of ligaments as described below:

Suspenory Ligament: attaches ovary to the positioning the ovaries in a craniocaudal orientation of the pelvic wall, within it are the ovarian vessels
  - Mesovarium attaches ovaries to the broad ligament. It transmits nerves and vessels to the ovary
  - Ovarian Ligament Proper: Fibro-muscular band extending from ovary to uterine cornu
  - Broad ligament: This is located below the proper ovarian ligament
  - Mesosalpinx: This is the fibro-muscular band between the fallopian tube and proper ovarian ligament

The ovaries often lie adjacent to the iliopsoas muscle within which lies an echogenic femoral nerve sheet.
The ovaries have dual blood supply - the Internal Iliac vessels which lie posterior to the ovary and the ovarian vessels which lie supero-lateral to the ovary. Both vessels are landmarks in the sonographic imaging of the ovary. Drainage of the ovaries is via the venous plexus.

**The Pregnant Uterus**
Through dynamic activities of complex interactions of the hypothalamic, pituitary and ovarian hormones, there is a release of one or more ovum/ova which if successfully fertilized by a spermatozoon become(s) a zygote (conception occurs at 2 weeks post menstrual age) which undergoes a process of maturation (zygote → morula → blastocyst → embryo).

The blastocyst usually implants in the prepared endometrium at the upper part of the corpus uteri between 21 and 24 days after the Last Menstrual Period (LMP). At this time the serum β-HCG value is positive and a decidual reaction is seen throughout the endometrium. Though a thin hyperechoic line (Fig 10.2) may be seen in the expected location of the uterine cavity (small white arrows), the first specific diagnostic sonographic feature of IUP is the visualization of the decidua – chorionic sac (gestational sac) at 32-35 days (Figure 10.2).

![Fig 10.2: The earliest appearance of the pregnant uterus on Transvaginal scanning EC: Endometrial cavity. C: Chorionic sac](image-url)
The decidua basalis underlies the conception while the decidua capsularis covers the luminal surface. The rest of the endometrium lining the uterine cavity is the decidua perietalis which is about 4-10mm thick.

![Decidua Basalis; DC: Decidua Capsularis; DP: Decidua Parietalis. Courtesy: Frank Netter’s Atlas of Anatomy.(Fig 10.2B)](image)

Fig 10.3: The pregnant uterus in the first trimester demonstrating layers of the decidua. DB: Decidua Basalis; DC: Decidua Capsularis; DP: Decidua Parietalis. Courtesy: Frank Netter’s Atlas of Anatomy.(Fig 10.2B)

This write-up which is majorly from a compilation of lectures given by various lecturers in the Centre for Ultrasound Research and Education, Medilag Consult, College of Medicine of the University of Lagos, hereafter, will focus on the anatomic changes in the uterus, the gestational sac and its content, the principles behind the Protocol for sonographic imaging of the pregnant uterus and its contents and the findings thereof.

**Protocol for obstetric ultrasonography:**

Protocols in healthcare delivery in general and specifically in obstetrics ultrasonography are predetermined written procedural methods of conducting/delivering health care services.

In obstetric ultrasonography this is of utmost importance to ensure adequate evaluation of both the mother and her fetus(es). Departmental protocols should therefore be strictly adhered to as Obstetric scanning must be purposeful.

Normal duration of pregnancy spans 40 weeks which are divided into three distinct periods, each one (trimesters) spanning 13 weeks. Each trimester has definite characteristics, all of which have distinct information that aids adequate management of the fetus and its carrier (the mother).
The protocol of each of these trimesters will be described in details with the objective of:
1. Listing the indications for scanning in each trimester.
2. Defining the timing of sonography in the pregnancy.
3. Describing the techniques of scanning in each trimester.
4. Describing the pitfalls of scanning in pregnancy.

Indications for scanning in the first trimester:
1. Confirm and date pregnancy.
2. Localize the gestational sac intrauterine or extra-uterine gestation.
3. Assess the viability of the gestation.
4. Determine any compromising features in the pregnant uterus.
5. Assess the symptomatic pregnant woman.

Indication for sonography in second and third trimesters:
- Fetal dating
- Fetal anatomy
- Scout for detection of risks in the pregnant woman
  - Multiple gestation
  - Fetal anomalies
  - Gross fetal anomalies
  - Poor obstetric history
- Monitor pelvic masses
- Evaluate maternal abdomino-pelvic structures especially when symptomatic
- Hypertension in pregnancy when kidneys must be evaluated as a matter of necessity.

Timing of scanning in pregnancy.
A minimum of two sonographic studies are suggested for uneventful gestation as follows:

- Between the 10th and 12th weeks for dating the fetus.
- 20-25 weeks for fetal anomalies.
- Scanning should however be more fragment in the at-risk –gestating such as:
  - multiple gestations which will require monthly ups.
  - low lying placenta which will require repeat study at 30 – 32 weeks for definitive localization of the placenta.
  - in growth retardation or feta distress serial monitoring of fetal weight and Doppler evaluation of the umbilical cord and placenta for early detection of any form of compromise of the fetus’ survival.
  - for fetuses in distress estimating the biophysical profile is of utmost importance.
**Scanning requirements**
The examination room must be warm, clean and friendly. Privacy must be maintained. The examination couch must have clean linen on it with additional linen for covering the patient’s pelvic region to her feet. The ultrasound gel must be kept warm and the patient informed before applying it on her. There must be the availability of nearby toilet.

Patient lies supine on the couch for trans-abdominal scanning and Trendelenberg for transvaginal scanning.

The area of interest is exposed and the rest decently covered with the additional linen. Photo-documentation of vital findings. Brief History should be taken from the patient to include the date of the first day of last menstruation (LMP); Status of pregnancy test? What the suspected problem is? What needs to be ruled out?

**First trimester scanning**
Patient Preparation: The patient should be requested to fill the bladder by drinking about 75 -150mls of water, waiting for 30 -45 minutes thereafter, to allow the filtration of water drunk into the bladder.

Filling the bladder has the advantages of
(a) producing an excellent acoustic window through which the structures posterior to the uterus can be visualized.
(b) Pushing cephalad, bowel loops that are located in the pelvis, thus enhancing adequate visualization of pelvic structures for transvaginal ultrasonography an empty bladder in required.

No specific prep except empty bladder. Explain to patient and reassure. Use examination table with leg supports or elevate hips. Apply Ultrasound gel on the 7.5MHz Sector Transducer and then cover Transducer with Transducer cover. Apply Gel on the Transducer cover.

The patient should be allowed to introduce the Transducer, thereafter the sinologist/sonographer, takes the handle of the Transducer and continues the examination.

First, a pelvic survey is performed. Since the Bladder’s position is consistent it is used to orientate the Transducer. The Transducer should be rotated through 90° to view uterus and adnexae. It is then swept along the sagittal plane from midline to pelvic side walls; then rotate to coronal & sweep from cervix to fundus.
Both adnexae are identified and should be checked for double ring gestational sac which will suggest ectopic gestation. Ovaries are seen as less echogenic & homogenous than uterus with the Internal iliac artery’s position and peripherally located round anechoic follicles helping to identify. Content of the uterus should be assessed.

Figure 10.4: Schematic diagram demonstrating transvaginal transducer-in-situ. Courtesy Callen’s Textbook of Obstetrics Ultrasonography

The transducer should be soaked in disinfectant between uses.

Transabdominal Ultrasonography requires the use of 3.5MHz Transducer. A general survey of the entire abdominopelvic areas is carried out. Maximum use of the available control knobs is essential for optimizing the images produced. These knobs include, measuring cursors, zoom button for enlarging the captured image for effect, M-mode button for counting cardiac pulsations; Keyboard for taking measurements and labeling notable findings..

The purposes of both methods of scanning in the first trimester are to identify the following:

1. Gestational sacs
   a. for location – intrauterine or extrauterine

Fig 10.5: Ectopic pregnancy with echogenic fluid collection in the peritoneal cavity, indicating complicated ectopic pregnancy
b. number of gestational sacs. If more than one, determine chorionicity and amnionicity.
c. Determine Gestational age using Mean Sac Diameter (MSD) which is measured by imaging the identified gestational sac along its sagittal and transverse planes taking measurements of the Length, Width and Antero-posterior dimensions of the Gestational Sac, summing the values up and dividing the sum by three:

\[
MSD = \frac{L+W+AP_{\text{mm}}}{3}
\]

Echogenic rim of the gestational sac must not be included in this measurement.

![Figure 10.6](image1.png)

Figure 10.6: Demonstrates the measurement of the Gestational sac. Note that the echogenic ring is not included in the measurement.

![Figure 10.7](image2.png)

Figure 10.7: Sagittal and Transverse views of the pregnant uterus demonstrating the measurements of Length (Sagittal view), Width and Antero-posterior (Transverse view) dimensions.
2. If a fetal pole is seen within the Gestational Sac, its crown-rump length is measured. This measurement is taken from the crown of the fetus to its rump. It is the most accurate measurement for estimation of gestational age between 9th and 14th weeks. The Yolk sac and the fetal limbs must not be included in the CRL measurement.

Caveats
Mean sac diameter MSD is most accurate between 5-11 weeks
Add 30 to MSD to get GA in days. Eg 5mm = 35d
Yolk sac with no embryo or FH = 5.5w
FH but CRL too small to measure=6w
6-12w, CRL most accurate.
6-10w, CRL increases by 1mm/day

3. The observed fetus should also be assessed for cardiac activity, nuchal translucency which is an anechoic space on the posterior part of the neck. When thicker than 3mm, it is a marker for fetal anomalies. Its thickness, measure from inner wall to inner wall at the level of C1/C2 should not exceed 3mm at 10-14 weeks.
4. The yolk sac which is the embryo’s food source should also be visualized between the 36th and 40th day when the Gestational sac is between 6-9mm. It should be round, thin walled and cystic. A 2006 Report stated that its size should not exceed 8.1mm in a viable gestation. Irregularity of its shape, its enlargement even in an embryo with cardiac pulsations are poor prognostic indicators.

5. The uterine wall should also be assessed for abnormalities like leiomyoma. Its location, size and features should be documented. Any abnormal collection should be queried as it could be subchorionic haemorrhage which is a predictor of poor status of the gestation.
Fig. 10.11: Transvaginal image of the uterus in early gestation showing empty gestational sac with crescent-shaped hemorrhage superiorly. Findings are consistent with 1st trimester pregnancy failure.

6. The Cervix should also be sighted. It should normally be closed, should have no fluid flowing through it.
7. The maternal adnexae, ovaries, kidneys should be evaluated.
8. Maternal symptoms should also be evaluated e.g. pregnancy induced hypertension when the maternal heart, kidneys should be carefully evaluated.

PROTOCOL FOR SECOND AND THIRD TRIMESTER SCANNING
Patient preparation and patient positioning are almost as in first trimester scanning. It should be borne in mind though, that due to the larger size of the fetus and the increased volume of amniotic fluid, the bladder filling in second and third trimesters should be moderate or none at all.

In addition, it must be borne in mind that for long scanning periods while the mother is in supination, the weight of the pregnant uterus on the Inferior Vena Cava can compromise blood flow to the brain. In such length studies therefore, the patient’s position must be regularly change to the lateral decubitus position to relieve the patient of this challenge.

Scanning must be done methodically, starting with a panoramic view of the entire uterus and abdomino pelvic region, moving from left to right caudally to cranially.

What to look for
- number of fetus(es)
- presentation
- other gross pathologies
TECHNIQUE
Beginning in the pelvis, centrally, the transducer should be placed along the sagittal plane to detect the head of the fetus. If the presentation in cephalic, the transducer is turned clockwise till a true axial section of the fetal head is obtained. The transducer should then be slid caudally (fetus’) from the fetal head through the neck, chest, abdomen noting the appearances of the structures in the axial plain, the plane on which most information is obtained on 2D greyscale scanning.

This movement continues till the limbs, umbilical cord, placenta, amniotic fluid, uterine wall and cervix are visualized.

Maternal pelvic structures should also be visualized in this sweep. This same of mode of methodical movement of the Transducer over the body parts of the fetus, from methodically