Chapter

Introductory Chapter: Common Pitfalls and How to Overcome

Samia Ali Abdo Gamie

1. Introduction

Medical ultrasound is an imaging modality using high-frequency sound waves to recognize unique tissue characteristics. The normal human range of audible sound is from 20 Hz to 20 KHz; in contrast the frequency used in medical ultrasound is >20,000 Hz. The frequency range that is used for medical imaging is generally between 2 and 18 MHz [1].

Piezoelectric effect discovered by Pierre and Jacques Curie in 1880 is the basic principle of ultrasound transducer. They discovered that when pressure is applied to quartz or some certain crystals, it creates an electrical charge in that material. Curie's brothers soon discovered the inverse piezoelectric effect; when an electric field was enforced onto crystal leads, it led to a disorder in the crystal lead—now called the inverse piezoelectric effect [2].

Piezoelectric transducer generates the ultrasound beam as a pulse travels through the tissue; the echo signals return to the transducer after undergoing absorption, reflection, and refraction depending on the tissue structure, leading to a real grayscale image formation. The basic rules in image formation can be summarized as follows. First, ultrasound pulse travels in a straight line, so echo signals travel in a narrow beam, giving a real-time scanning. Second, as the velocity of the ultrasound is constant, the distance is directly proportional to how far the structure is from the transducer. Third, the echo strength is related to the tissue reaction with the ultrasound waves; the reflected waves give the echo brightness on the screen that is referred to as tissue echogenicity [3].

Physics of the ultrasound is essential for all physicians to understand and interpret ultrasound images. Frequency is the number of the sound waves per second. It usually remains constant maintaining the frequency of the original source, but the velocity of the ultrasound wave changes depending on the physical properties of the medium. These variations in velocity introduce artifacts into the image, mainly attributed to bone and fat. The frequency of transducer determines the resolution of the ultrasound image. The resolution of the ultrasound machine is its ability to detect and display two close structures as distinct. Higher-frequency transducers have higher resolution, but its ability to penetrate to deep structures is low; therefore it is used for superficial structures. On the other hand, low-frequency transducers can penetrate to deep structures with lesser resolution; therefore it is suitable for deeper structures. Using high transducers of high frequency to screen deep structures results in more attenuation to the image of the deep tissue [4]. Choosing the proper transducer for a proper image of different organs is based on this rule of thumb regarding the transducer's frequency. Therefore, always use a sector transducer from 3.5 to 5 MHz to screen deep abdominal structures but higher frequency for superficial structures [5].

Practical image orientation is performed in two planes sagittal plane and transverse plane. Using the transducer in the sagittal plane, the left side of the image represents the cranial plane. Meanwhile putting the transducer in a transverse plane, the left side of the image represents the right side of the patient. Abdominal examination is usually started while the patient is lying comfortably in supine position, and then they must be examined on both sides. Systematic scanning is important; scanning of all organs and all areas is essential to complete your mental checklist in an ultrasound report.

Preparation for abdominal ultrasound generally requires fasting for 8 h, decreasing the gas in the intestine. Also, for the gall bladder and biliary tree exploration, fasting is essential for screening. Other conditions such as emergency ultrasound require no special preparations. In each chapter of this book, if any special preparation for screening the organ is required, it will be mentioned.

In practice, ultrasound artifacts are common; thus understanding these artifacts' physics is vital to help correct it to improve the images, leading to good interpretation for a correct diagnosis. The artifacts arise either from improper operator technique or from the physics of ultrasound transmission and traveling. Identification of the artifact from improper technique is the first step, so it can be avoided. The second step is to know how the physics' artifacts can be corrected, keeping in mind that some of these artifacts may be good clues for proper diagnosis of structures with special characteristics. In this book, in each chapter, we try to explain some of these artifacts and how to avoid them. Potential US artifact correction is important for image quality improvement, optimal interpretation, and diagnosis.

Artifacts can be classified into two: One, related to the beam and the resolution, and the other, related to the location and the attenuation. Here are some common examples of these artifacts, their clinical relevance, their physical mechanism, and how to make alteration.

Beam- and resolution-related artifacts

Beamwidth artifact: Lateral resolution is the ability to detect two close points in the transverse plane as two distinct points. It leads to lateral blurring of the image and aberrant echoes from adjacent highly echogenic objects. It can be reduced by focusing the sound selection. Focusing improves the beamwidth, so it becomes narrower at the target focal zone [6].

Section thickness artifact: It is the ability to distinguish two vertical beams as two distinct points. It is called elevation resolution as the point planes are perpendicular to the transducer plane. It appears like debris in anechoic structure as cyst or ascites. It can be overcome by putting it in a focal zone with a standoff pad [7].

Secondary lobe artifacts: It mimics debris in anechoic structures. It is from the reflected echo that comes back from ultrasound waves that are transmitted outside the beam. It can be corrected by reducing the gain [8].

Location characteristics ultrasound artifact

Reverberation artifact: It appears as multiple bright parallel lines at regular intervals that decrease in intensity as the depth increase. It is due to reflections between highly reflective interfaces in parallel (reverberates). It may be useful in the detection of air in abnormal locations, as in pneumatosis, pneumoperitoneum, and pneumobilia. It can be reduced by decreasing gain, changing the angle of insonation, or using multiple windows [9].

Comet tail artifact: Adenomyomatosis, based on the same principle of reverberation artifact. It is caused by highly reflective interfaces that are closely spaced, so the individual echoes cannot be distinguishable. This artifact is useful as it considered a fingerprint for identification and diagnosis of cholesterol crystals in adenomyomatosis of the gallbladder (**Figure 1**) [10].

Ring-down artifacts: It arises from resonant vibrations within trapped air bubbles. These vibrations produce a continuous sound wave transmitted back to the transducer; it appears as a streak or series of parallel bands deep to a focus of gas. It can be useful in identifying abnormal foci of air, e.g., pneumoperitoneum and portal venous gas. Also, it can be indicative of appendicitis if it is detected in the appendix [11].

Mirror image artifact: It mimics disease, such as pseudo-thickened bowel wall and lesions in the lung. It is due to reflections of a highly reflective structure, e.g., the diaphragm, producing a mirror-like image of an object. The second image is generated along that path, deeper than the true site of the structure due to increased time of the return echo. A common example is in the case of a liver lesion near the diaphragm; the transmitted beam is reflected off the diaphragm and will be faced with a liver lesion that reflects it to the diaphragm again as well as the transducer. The image on the screen contains two lesions similar on both sides of the diaphragm and the same distance from it (**Figure 2**). This type of artifact may be corrected by decreasing gain or changing the angle of insonation [11].

Accentuation and attenuation characteristics of ultrasound artifacts

Increased transmission (accentuation): It is due to increased intensity of echoes distal to a low-attenuating structure. It is useful in practice to differentiate between cystic and solid structures. Distal to cystic structure there is an increased echo intensity, as the ultrasound waves pass through the cystic structure without any disturbance or loss. This accentuation is important to confirm the diagnosis of the anechoic cystic lesion (**Figure 3**). It can be increased by using tissue harmonic imaging [12].

Attenuation artifacts: Attenuation is a loss of ultrasound energy and amplitude as it goes deeper through the tissue. Therefore, echo from deeper structure comes weaker than the echo from the superficial structure; the ultrasound machine is computerized to amplify the return echo from the deeper structures. If the tissue is reflective, as in the case of a fat tissue, less echo reaches the deeper structure, and screening will be difficult. This attenuation is adequately compensated by first-order correction schemes such as time gain compensation.

Acoustic shadowing: It is due to a reduction in echo strength distal to a highly reflective object. Three types of acoustic shadowing, clean, partial, and dirty,

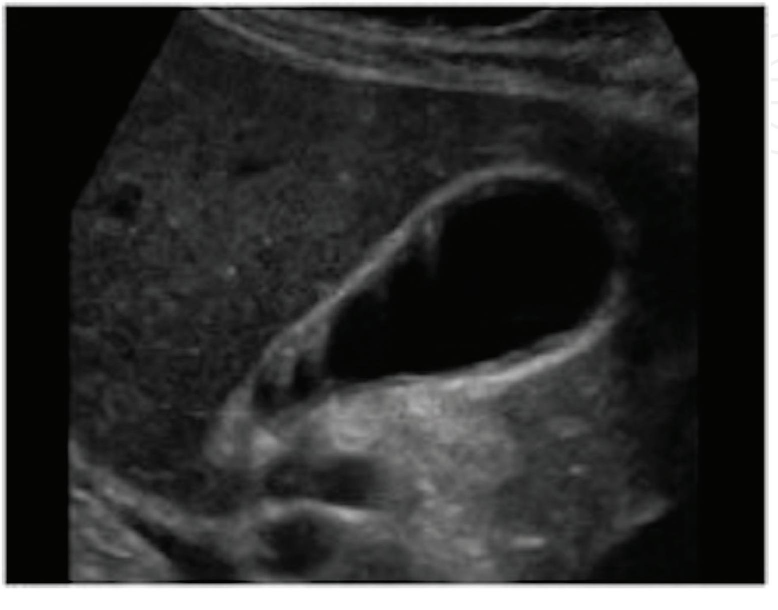

Figure 1.
Longitudinal US image of the gallbladder shows comet tail artifact caused by cholesterol crystals in Rokitansky-Aschoff sinuses. This finding is diagnostic of adenomyomatosis.

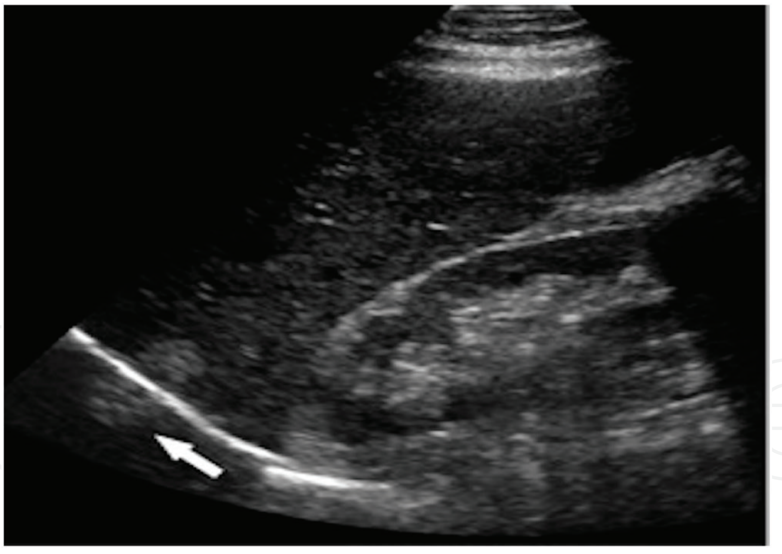

Figure 2.
Longitudinal US image shows an echogenic lesion in the right hepatic lobe (hepatic hemangioma), and a duplicated echogenic lesion (arrow) on the other side equidistant from the diaphragm mimics lesion in lung parenchyma.

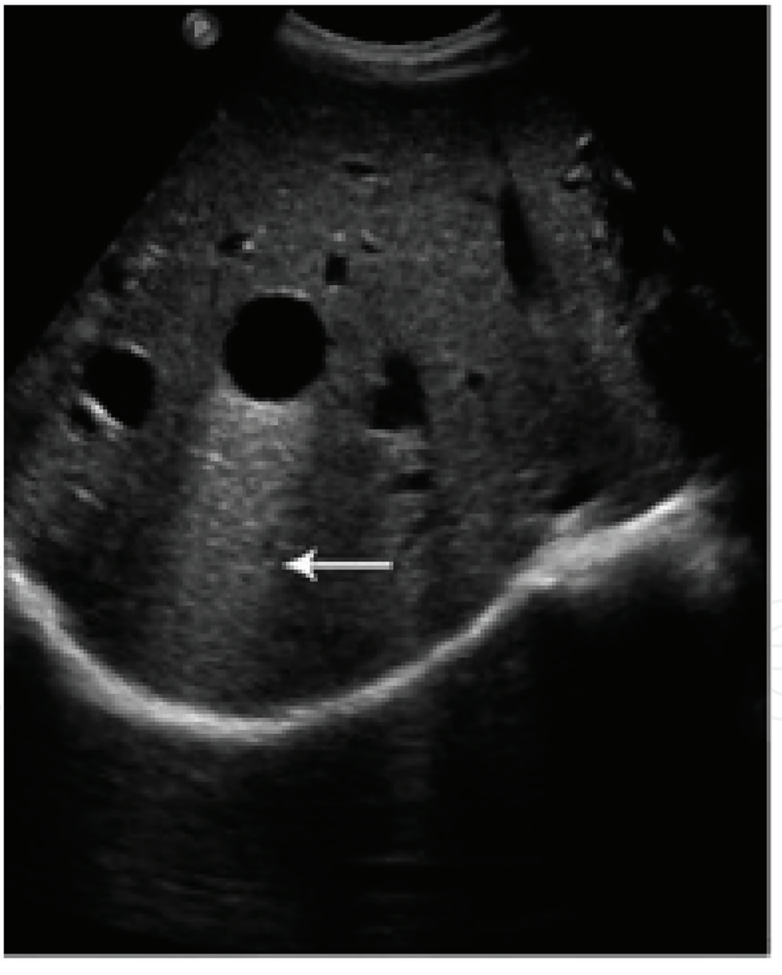

Figure 3.
Transverse US image of the liver shows anechoic hepatic cysts. The hepatic parenchyma distal to the cysts is falsely displayed as increased intensity (arrow) secondary to increased through-transmission artifact.

are used to describe the shadow of stones, calcification, and air, respectively. It is very helpful in practice to identify the clear shadow as a dark band due to all the ultrasound waves being absorbed. Its presence can help detect stones in echogenic structures such as kidney stones. Also, a shadow is important to differentiate a gall bladder (GB) stone (**Figure 4**), with its clear shadow, from a non-shadowing polyp or a sludge ball in GB. Dirty shadowing is seen in the case of highly refracting structure like gas. In clinical practice, it is important to increase the shadowing to help with the diagnosis of important pathology, so the focal zone and beam width are important to be adjusted in these cases [11].

The edge (refraction) artifact: It occurs in rounded structures like a cyst or urinary bladder as the ultrasound refracted at its edges results in shadows at both edges (**Figure 5**). These artifact shadows are corrected, and the shadows disappear by changing the angle of the ultrasound beam after identification of the artifact.

Anisotropy: It commonly occurs in tendons and, to a lesser extent, muscles, ligaments, and nerves. It appears as a hypoechoic area in a structure that has anisotropy. This phenomenon can be misinterpreted as a discontinuation of the course's structure. As the ultrasound beam is perpendicular to the tendon throughout its course, the tendon is uniformly hyperechoic. If the tendon is curved, the ultrasound beam is not perpendicular to the tendon; the tendon becomes hypoechoic and disappears. These phenomena can be overcome by changing the transducer position (heel-to-toe movement to make the transducer perpendicular on the tendon along its course) [13].

Understanding of these artifacts will minimize any misinterpretation in the report, and in certain situations it helps in the diagnosis. In this book, we used some of these artifact expressions for diagnosis or for explaining how to avoid any mistakes during scanning.

Standardized evaluation of abdominal ultrasound should optimally take place after overnight fasting in most of the ultrasound techniques; however, this is not a condition in urgent situations. In an emergency ultrasound, no special preparation is required. In routine clinical practice, fasting is important to avoid interfering bowel gas; also, it is recommended to assess the abdomen from a more lateral aspect through both flanks. Keeping in mind the need to take precautions, and being systematic in scanning, will provide clues to reach the correct diagnosis and avoid misinterpretation.

Starting ultrasound examination of the abdomen, it is usually done in a systematic manner. Your guide for scanning must be based on your mental checklist in the examination. Start by the right side considering the liver the acoustic window of the right upper quadrant of the abdomen. Go through the anatomical four areas of the abdomen, namely, the right upper quadrant, the left upper quadrant, the right lower quadrant, and the left lower quadrant. Intestinal loops can be screened in the

Figure 4.
Longitudinal US image of the gallbladder shows echogenic gallstones with clear shadow.

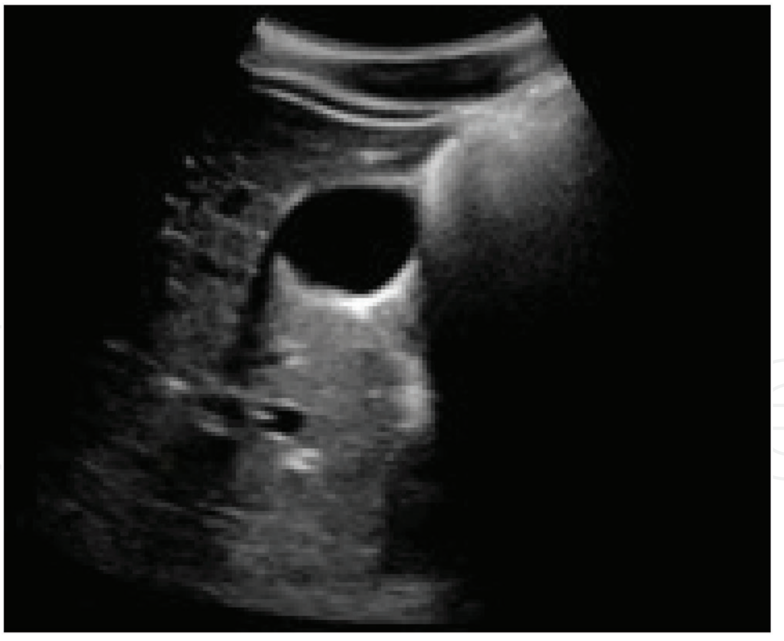

Figure 5.
Transverse US image of the liver shows transverse image of gallbladder with false shadow edge artifact.

"grid"-type pattern starting from the right side passing through the areas to the left side in a slow screening movement allowing to explore any intestinal pathology.

Ultrasound reports must fulfill all abdominal organs, with a full description of each in a systemic manner. A general outline of the sonographic description includes the architectures, the echogenicity of the parenchyma, and blood vessel distribution with a special comment on its variation from normal. The full screen of the organ is usually done with a complete orientation about the organ pathology. Any pathology is described as diffuse or localized, followed by detail descriptions of its site, size, echogenicity, regularity, and any special artifacts as mentioned above.

At the end of the report, there is a summary of the findings with your brainstorm conclusion. Ultrasound report is your mind checklist representing your systematic work and screening for the complete abdominal examination. Keep in mind that ultrasound findings are not histological but rather pathological. If from your clinical knowledge any additional investigation is required to confirm the diagnosis, it must be mentioned as a recommendation. Also, according to the ultrasound findings, a simple interventional process as ultrasound-guided biopsy procedures may be required. Also, good technical skills are needed for better interpretation of any valuable knowledge in the screening while avoiding the pitfalls and artifacts that can result in more confusion to the sonographers. In this text, many valuable technical skills are available from experts each in his field.

Author details

Samia Ali Abdo Gamie
Helwan University, Cairo, Egypt

*Address all correspondence to: samia_ali5@hotmail.com

References

[1] Hangiandreou NJ. AAPM/RSNA physics tutorial for residents. Topics in US: B-mode US: Basic concepts and new technology. RadioGraphics. 2003;**23**:1019-1033

[2] Genovese M. Journal of Diagnostic Medical Sonography Ultrasound Transducers. 2016;**32**(1):48-53

[3] Manbachi A, Cobbold RSC. Development and application of piezoelectric materials for ultrasound generation and detection. Ultrasound. 2011;**19**(4):187-196

[4] Abu-Zidan FM, Hefny AF, Corr P. Clinical ultrasound physics. Journal of Emergencies, Trauma, and Shock. 2011;**4**(4):501-503

[5] Szabo TL, Lewin PA. Ultrasound transducer selection in clinical imaging practice. Journal of Ultrasound in Medicine. 2013;**32**:573-582

[6] Bertrand PB, Levine RA, Isselbacher EM, Vandervoort PM. Fact or artifact in two-dimensional echocardiography: Avoiding misdiagnosis and missed diagnosis. Journal of the American Society of Echocardiography. 2016;**29**(5):381-391

[7] Hoskins PR, Martin K, Thrush A. Diagnostic Ultrasound: Physics and Equipment. 2nd ed. Cambridge: Cambridge, England; 2010

[8] Middleton WD, Siegel MJ, Dahiya N. Ultrasound artifacts. In: Siegel MJ, editor. Pediatric Sonography. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2011. pp. 21-42

[9] Baad M, Lu ZF, Reiser I, Paushter D. Clinical significance of US artifacts. RadioGraphics. 2017;**37**:1408-1423

[10] Bonatti M, Vezzali N, Lombardo F, Ferro F, Zamboni G, Tauber M, et al. Gallbladder adenomyomatosis: Imaging findings, tricks and pitfalls. Insights into Imaging. 2017;**8**(2):243-253

[11] Feldman MK, Katyal S, Blackwood MS. US artifacts. RadioGraphics. 2009;**29**:1179-1189

[12] Rose JS, Bair AE. Fundamentals of ultrasound. In: Cosby KS, Kendall JL, editors. Practical Guide to Emergency Ultrasound. PA: Lippincott Williams and Wilkins; 2006. pp. 27-41

[13] Serafin-Król M, Maliborski A. Diagnostic errors in musculoskeletal ultrasound imaging and how to avoid them. Journal of Ultrasonography. 2017;**17**(70):188-196