Ultrasound Imaging and Advances in System Features

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- Ultrasound • Auto-optimization • 3-D imaging
- 4-D imaging • Digital technology • Fusion imaging

Ultrasound physics is the basis of all ultrasound imaging and is a complex subject. All diagnostic ultrasound images are created using an ultrasound machine and an ultrasound transducer. An electric current is applied to a piezoelectric crystal, which produces an ultrasound beam. The returning signal from that ultrasound beam is then processed by a beam transformer and displayed on a monitor to be viewed as an ultrasound image. This is a simplified description of how an ultrasound image is created. The purpose of this article is to introduce readers to newer technologies used in diagnostic ultrasound imaging, not to provide readers with detailed information in the science of ultrasound physics and image creation. Trained operators of any piece of ultrasound equipment should know these basic principles in order to understand how their equipment works and to understand the basics of ultrasound imaging and image acquisition. The basics of ultrasound physics will never change. What has changed is the use of newer digital technologies and innovative engineering ideas that are used in the development and manufacturing of ultrasound machines and transducers today. These new technologies are changing the way basic physical principles are used in the applications of ultrasound. It would not matter how much technology a piece of equipment has if an operator of the equipment did not have basic knowledge in the principles of ultrasound physics. It is this knowledge that allows operators to maximize each system's features to acquire images, differentiate between what is real and what is artifact, and image the area of interest adequately for diagnostic interpretation by a qualified professional. This is an exciting time in ultrasound imaging because newer applications in the use of ultrasound in imaging for the diagnosis of disease are developed every day. Using a combination of powerful new engineering tools, an ultrasound beam and the miniaturization of transducers and machines have made the imaging possibilities in ultrasound limitless. This article reviews basic system features and provides an overview of advances in ultrasound technology.

BASIC EQUIPMENT FEATURES AND 2-D REAL-TIME ULTRASOUND IMAGING

All ultrasound machines operate on these basic principles: electrical generation of a sound wave and ultrasound beam; reception of the returning echoes; and processing of the returning signal for display. The standard gray-scale real-time image is referred to as 2-D real-time (live) imaging. 2-D real-time imaging consists of two spatial coordinates plotted against time for the returning ultrasound echo. Each detected echo is determined by a scan line using the echo range principle and the speed of sound through tissue (average velocity of sound through tissue is 1540 cm/s). The sound wave produced must have an ultrasound frequency that is greater than 20 kHz and is of uniform intensity with good spatial resolution.[1] Beam formation is accomplished through a combination of internal system components, applied transducer technology, and transducer construction. Manufacturers strive to provide innovative transducer technology that results in the highest-quality axial and lateral resolution with improved

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depth penetration. Axial resolution and lateral resolution are determined by the number of transducer elements and the number of channels. Axial resolution and lateral resolution are the two key ultrasound requirements that must be present to provide high-resolution, quality ultrasound images. Axial resolution is the ultrasound system's ability to see the smallest detectable object along the perpendicular axis of the beam. Lateral resolution is the ultrasound system's ability to distinguish two objects adjacent to each other that are oriented perpendicular to the ultrasound beam.[1] Transducer frequency is another important factor in image quality. Higher-frequency transducers provide higher-quality images with excellent axial and lateral resolution. Today's ultrasound transducers are multifrequency transducers that image for detail at higher frequencies and use lower frequencies for better depth penetration. Multifrequency transducers allow operators to image with improved axial and lateral resolution without the need to use multiple transducers during the performance of an examination.

Basic system features, such as overall gain (transmit power in decibels), time gain compensation, dynamic range (in decibels), field of view (or depth), and focal zones (region of minimum beam width), comprise the basic tools to producing an ultrasound image.[1] Because newer systems have enhanced technology to improve the speed of image acquisition, it is possible to add multiple focal zones to an image without compromising frame rate. Manufacturers have improved equipments' ability to scan with more than two focal zones on, scan at much deeper depths, and maintain fast frame rates. The ability to scan with the entire region of interest in focus and at deeper depths is critical to aiding an operator's ability to find and image normal anatomy and pathology within these areas.

Some new features used to enhance old technology are the addition of auto-optimization buttons or automatic system image adjustments, which allow operators to adjust the sound beam for the organ-specific region of interest. The auto-optimization feature adjusts the image for differences in the speed of sound in varying types of organ tissues and enhances the ability to see these tissue differences. A simple explanation of auto-optimization is to describe it as an automatic adjustment to the image quality that otherwise would have to be adjusted by an operator. Auto-optimization assists in bringing out some of the ultrasound image detail, or contrast differences, that might not have been seen before its application.[2] It is useful for imaging anechoic areas adjacent to soft tissue and subtle masses in an organ and for bringing out details that require higher than normal levels of contrast. Some systems automatically adjust to these changes as the transducer is moved whereas others require an operator to turn auto-optimization on or off as needed. Some manufacturers program this feature to automatically adjust the time gain compensation and overall gain controls with movement of the transducer or as auto-optimization is applied.[2]

ADVANCES IN ULTRASOUND TECHNOLOGY: BUILDING A SMALLER ULTRASOUND UNIT

The past decade has seen some dramatic changes in ultrasound imaging. Each year researchers have developed new digital ultrasound technology that aids in the diagnosis and treatment of disease processes without the use of ionizing radiation. Digital computerized technology and microprocessors have made it possible for manufacturers to develop powerful equipment and allow them package it in smaller, lightweight, mobile units. Some of the newest generations of ultrasound units are small enough to place in a laboratory coat pocket and light enough to take anywhere. These newer units offer the ability to obtain exceptional quality images at a fraction of the cost of a full-sized unit. The laptop-sized machines have made it possible to perform diagnostic high-quality images that are equivalent in quality to those from higher-end pieces of equipment. These smaller units have also made it possible to take them to locations and perform ultrasound examinations where they has not been able to be done before. Emergency departments across the United States have integrated these small units for use in trauma assessments, or quick scans, and for easy access to vessels for central line placements. Most emergency department training programs for physicians now include training in the use of ultrasound in an emergency department setting. These units have also become popular within the sports medicine field and are routinely used during athletic events for instant diagnosis of sports injuries. These compact units are also battery operated, an added feature to their compact size and portability. These smaller ultrasound units have also become attractive to the veterinary medicine field where they are portable enough to take directly to an animal to use as an assessment tool for diagnostic purposes. Medical professionals can bring the equipment to patients and diagnose disease in a much shorter period of time than previously. Use of compact, portable ultrasound technology for diagnostic purposes