Abstract

Although most urologists use transrectal ultrasound imaging of the prostate predominantly as a tool to accurately direct biopsies, identification of prostatic abnormalities on sonographic images can be critical in some patients.\(^1\) To accurately decipher the pathology conveyed in the areas of shadow and brightness displayed in ultrasound images, an understanding of the physical principles generating these images is essential.\(^2\)

**Keywords:** ultrasound, hypoechoic, imaging

Basic Concepts

Ultrasound is defined as sound with a frequency too high for the human ear to hear.\(^3,4\) Frequency, or the number of sound waves per second, is measured in hertz (Hz). Sound with a frequency over 20 kilohertz (kHz) is outside human hearing range. Transrectal prostate ultrasound is generally performed at very high frequencies of 5–10 megahertz (mHz). By comparison, adult renal imaging is performed at frequencies of 2–3 mHz.

Wavelength is the distance between the onset of one sound wave to the next. In general, as wavelength increases, frequency decreases. The relationship of the wavelength to the frequency defines the velocity. Velocity
is the speed at which sound waves travel through a particular medium or tissue, and is equal to the frequency multiplied by the wavelength. This becomes clinically important when interpreting ultrasound because velocity depends upon the medium through which the ultrasound wave is traveling. The velocity through human soft tissues is approximately 1540 meters per second, very similar to the velocity through water. The change in velocity when ultrasound waves encounter air, bone, and other structures accounts for many of the artifacts and landmarks encountered during ultrasound imaging. For example, air has a velocity of 330 meters per second, dramatically lower than soft tissue. Therefore, when air is present between the ultrasound probe and the tissue of interest, the image can be distorted or completely obscured. For this reason, a water-density substance, termed a coupling medium, is used for transmission of the ultrasound waves across the space between the transducer and the body surface, where air pockets frequently occur. This coupling medium is usually a sonographic jelly or lubricant and should be placed between the probe and the rectal surface as well as between the probe and any protective sheaths covering the probe.

Acoustic impedance refers to how resistant a particular structure is to penetration by sound waves. As sound waves progress through tissues with varying impedance characteristics, they decrease in amplitude, a process called attenuation. Higher frequencies are attenuated by tissue more than lower frequencies. A key component of successful ultrasound imaging is accurately establishing settings on the ultrasound console to amplify attenuated echoes. This process of amplification is known as time-gain compensation. The goal is increasing amplification of more distant sound waves to generate a uniform image rather than an image that is very bright near the transducer and rapidly becomes too dark to distinguish structures progressively further from the transducer. The appropriate time-gain compensation varies with the location being studied, the organ of interest, the distance from the transducer to the area of interest, and the characteristics of the tissue between the transducer and the area of interest. Most ultrasound consoles with a capacity for transrectal prostate ultrasonography include factory-installed default settings for optimal time-gain compensation in prostate imaging.

**Ultrasound Transmission**

Ultrasound waves are generated by a transducer. The transducer contains the transmitting element, electrodes, and protective face. The transducer, focusing and steering mechanisms, scanning apparatus, and associated wiring for connection to the ultrasound console are housed in an ultrasound probe which is shaped for the desired application, such as cylindrical for transrectal ultrasonography. Some authors refer to the entire ultrasound probe as the transducer.