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Image-guided Radiation Therapy: Ultrasonography

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Image-guided Radiation Therapy: Ultrasonography

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Today's radiation therapy technology requires image guidance to precisely target tumor pathology and to maintain accuracy during treatment. Ultrasonography is a particularly useful form of image guidance for some types of cancer and anatomy such as the prostate.

This article explores the use of ultrasonography in image-guided radiation therapy, along with the fusion of sonograms to computed tomography scans, quality assurance for ultrasound equipment and ultrasound technique.

After completing this article, the reader should be able to:

- Identify appropriate uses of ultrasonography for image-guided radiation therapy.
- Describe ultrasound approaches and techniques used for image guidance.
- Discuss how ultrasonography can contribute to the planning and targeting of radiation treatments.
- Explain quality assurance procedures that should be performed on ultrasound equipment.

Radiation therapy is an important tool in the treatment of cancer, and recent technological advances have allowed practitioners to deliver higher and more targeted radiation doses to tumors. Today's complex treatments not only involve precise target localization, but they also require accurate planning and setup before and during treatment. Thus, medical imaging is playing an increasingly vital role in radiation oncology.

Image-guided radiation therapy (IGRT) uses various medical imaging modalities to direct radiation with greater accuracy to a known target. Nonionizing radiation modalities include ultrasonography, magnetic resonance (MR) imaging and surface imaging; ionizing radiation modalities include computed tomography (CT), cone-beam CT and portal imaging. With IGRT, a radiation oncologist can increase the radiation dose delivered to a tumor while minimizing the dose to the surrounding normal tissues.[1]

As IGRT becomes an integral part of high-dose radiation therapy, the radiation therapy team can now treat prostate cancer in 5 days compared with past treatment regimens that required 7 weeks. Also, brain tumors currently can be treated without attaching stabilization frames to a patient's head. These improvements are possible because imaging in radiation therapy allows visualization of internal anatomy before, during and after treatment.[1]

Before the routine use of IGRT, practitioners overestimated treatment volumes to take organ motion into account. The radiation oncology team now can use pretreatment sonograms, CT scans, positron emission tomography (PET) scans and MR images for treatment planning; these modalities have helped to significantly decrease

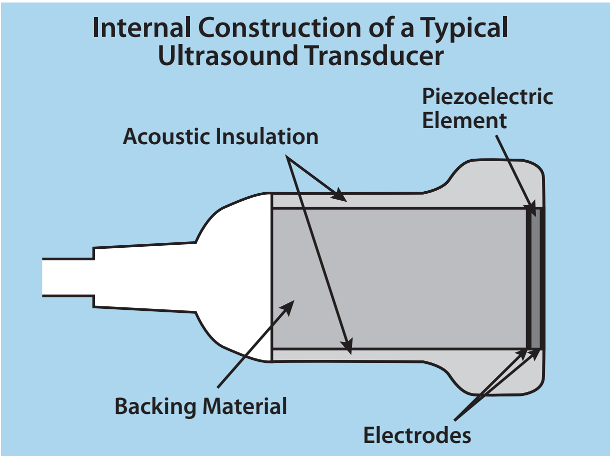

Figure 1. *Ultrasound transducer design. The tip of the transducer contains a piezoelectric material, usually a ceramic crystal layer. The transducer tip also includes electrodes that send an electrical pulse to the crystals. The pulse causes the crystals to vibrate and produce a sound wave that is transported into the body. As the sound encounters anatomical structures, it is absorbed, reflected or passes through the structures. Reflected sound waves return to the transducer, where they are converted to an electrical signal that then is transmitted to the system software for interpretation. Backing, or dampening, material and acoustic insulation is used to limit the ringing of the crystals as the transducer waits to receive the reflected sound; the dampening material also keeps the sound waves from reverberating backward.*

the size of margins. The use of medical imaging before treatment can define the tumor volume, reveal patient setup errors and display normal tissue location.[1]

Furthermore, images acquired during the course of treatment can be used to modify the treatment plan throughout radiation therapy delivery, a process called image-guided adaptive radiation therapy (IGART). Onboard imaging such as cone-beam CT, ultrasonography, electromagnetic tracking, internal and external fiducial tracking, and optical or video surface tracking systems are used to adjust the treatment plan to compensate for patient movement. With IGART, the treatment team can adapt the treatment plan before, during or after a fraction is completed and before delivering the next fraction.[2]

The planning and delivery of radiation therapy is fraught with many unavoidable uncertainties.[1] The greater the uncertainty concerning the location of the treatment volume, the larger the margins must be to ensure adequate tumor coverage. As higher doses are delivered in fewer fractions, radiation oncology practitioners must identify and reduce uncertainty to the lowest possible level. Medical imaging helps remove uncertainty regarding whether the target is in the treatment field.[1] The ability to deliver treatment with a remarkable understanding of internal anatomical structures during each fraction is what makes IGRT so powerful.[3]

Ultrasound Basics

Ultrasonography has long been used as an imaging tool for diagnostic and cardiovascular studies and for image-guided biopsies. The modality also has been adapted for use in radiation therapy. During ultrasound imaging, a small transducer called a probe transmits high-frequency sound waves through the body. The probe receives reflected waves, or echoes, from the body's tissues and then reconstructs those signals into a displayed image. Unlike other imaging modalities such as CT and radiography, ultrasonography does not use ionizing radiation.[2]

A radiation therapy-adapted ultrasound unit uses a wave frequency ranging from 1 to 5 megahertz (MHz), or cycles per second.[4] Sound waves of this frequency are inaudible to the human ear; the frequency of audible sound waves ranges from 20 Hz to 20 kHz. Sound waves are longitudinal mechanical waves. As they travel through a medium such as tissue, the waves oscillate matter in the direction that the wave travels.[2]

The physical principle by which the ultrasound transducer produces sound waves, receives the reflected waves and converts them into mechanical energy is called the piezoelectric effect. This phenomenon occurs when piezoelectric materials are mechanically oscillated or put under pressure, creating an acoustic wave (see **Figure 1**). Piezoelectric ceramic plates are usually made up of lead zirconate titanate.[5]

The transducer's size and shape affects the field of view covered by the sonogram (see **Figure 2**). **Figure 3** shows how ultrasound equipment produces a sonogram. First, the equipment sends an electrical signal to the piezoelectric material in the transducer. The electrical signal causes the material to deform and produce an acoustic wave, which then is sent into the body. The sound wave can be transmitted, absorbed or reflected by the body's tissues. The transducer receives echoes reflected by the tissues and converts the echoes into an