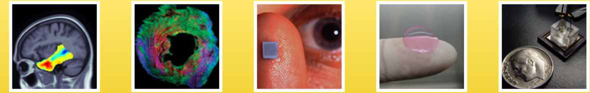


Ultrasound

What is medical ultrasound?

Medical ultrasound falls into two distinct categories: diagnostic and therapeutic:

Cross-section ultrasound image of a fetus
Source: Phillips Health Care- iu22xMATRIX system

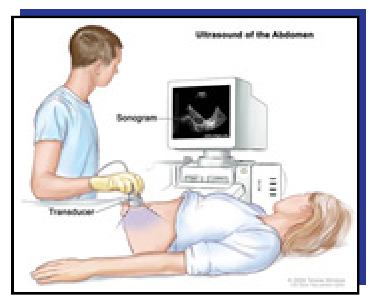
Diagnostic ultrasound is a non-invasive diagnostic technique used to image inside the body. Diagnostic ultrasound probes, called transducers, produce sound waves with frequencies above the threshold of human hearing (above 20KHz), but most transducers in current use operate at much higher frequencies (in the megahertz (MHz) range).

Diagnostic ultrasound can be further sub-divided into anatomical and functional ultrasound. Anatomical ultrasound produces images of the internal organs or other structures. Functional ultrasound combines information such as the movement and velocity of tissue or blood, softness or hardness of tissue, and other physical characteristics with anatomical images to create "information maps". These maps help doctors visualize changes/differences in function within a structure or organ.

Therapeutic ultrasound also uses sound waves above the range of human hearing but does not produce images. Its purpose is to interact with tissues in the body such that they are modified or destroyed. Among the modifications possible are: moving or pushing tissue, heating tissue, dissolving blood clots, or delivering drugs to specific locations in the body. The destructive functions are made possible by use of very high-intensity beams that can destroy diseased or abnormal tissues such as tumors. The advantage of using ultrasound therapies is that, in most cases, they are non-invasive.

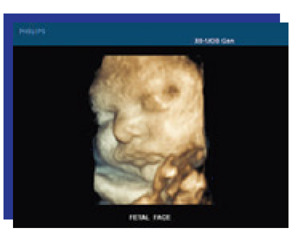
How does it work?

Ultrasound waves are produced by a transducer which can both emit ultrasound waves, as well as detect the ultrasound echoes reflected back. In most cases, the active elements in ultrasound transducers are made of special ceramic crystal materials called piezoelectrics. These materials are able to produce sound waves when an electric current passes through them, but can also work in reverse, producing electricity when a sound wave hits them. When used in an ultrasound scanner, the transducer sends out a directed beam of sound waves into the body, and the sound waves are reflected back to the transducer from the tissues and organs in the path of the beam. When these echoes hit the transducer, they generate electrical signals that the ultrasound scanner converts into images of the tissues and organs.



Ultrasound of the abdomen
Source: Terese Winslow

What is ultrasound used for?



3D ultrasound image of fetal face
Source: Courtesy of Phillips Health Care- iu22xMATRIX system

Diagnostic ultrasound is able to non-invasively image internal organs within the body. However, it is not good for imaging bones or tissues that contain air, like the lungs. Under some conditions, ultrasound can image bones (such as in a fetus or in small babies) or the lungs, when they are filled or partially filled with fluid. One of the most common uses of ultrasound is during pregnancy, to monitor the growth and development of the fetus, but there are many other uses, including imaging the heart, blood vessels, eyes, thyroid, brain, breast, abdominal organs, skin, and muscles. Ultrasound images are displayed in either 2D, 3D, or 4D (3D in motion).

Functional ultrasound applications include Doppler and color Doppler ultrasound for measuring and visualizing blood flow in vessels within the body or in the heart as well as the speed of the blood flow and direction of movement. This is done using color-coded maps called color Doppler imaging or by producing a graphical display of the actual velocity measurements of blood at specific locations in a blood vessel.

Another functional form of ultrasound is elastography, a method for measuring and displaying the relative stiffness of tissues which can be used to differentiate tumors from healthy tissue. This information can be displayed as either color-coded maps of the relative stiffness; black-and white maps that display high-contrast images of tumors compared with anatomical images; or color-coded maps that are overlayed on the anatomical image.

Ultrasound is also an important method for imaging interventions in the body. For example, ultrasound-guided needle biopsy helps physicians see the position of a needle while it is being guided to a selected target, such as a mass or a tumor in the breast.

Also, ultrasound is used for real-time imaging of the location of the tip of a catheter as it is inserted in a blood vessel and guided along the length of the vessel. It can also be used for minimally invasive surgery to guide the surgeon with real-time images of the inside of the body.

Therapeutic or interventional ultrasound produces high or very high levels of acoustic output that can be focused on specific targets for the purpose of heating, ablating, or breaking up tissue. Most uses of therapeutic ultrasound are still in the research stage, although at least one application—the ablation of uterine fibroids—has been approved by the FDA and is currently in clinical use. One type of therapeutic ultrasound uses high-intensity beams of sound that are highly focused, and is called High Intensity Focused Ultrasound (HIFU). HIFU is being investigated as a non-invasive method for modifying or destroying diseased or abnormal tissues inside the body (e.g. tumors) and could become a substitute for invasive surgery. It can be used to destroy a diseased or abnormal growth or lesion inside the body without having to open or tear the skin or cause damage to the surrounding tissue. This technique is also being investigated as a way to close wounds and stop bleeding as well as break up clots in blood vessels.

Are there risks?

Diagnostic ultrasound is generally safe and does not produce ionizing radiation like that produced by x-rays. Still, ultrasound is capable of producing some biological effects in the body under specific settings and conditions. For this reason, the FDA requires that diagnostic ultrasound devices operate within acceptable limits. Also, the FDA, as well as many professional societies, discourage the casual use of ultrasound (e.g. for keepsake videos) and recommend that it be used only when there is a true medical need.

What are examples of NIBIB-funded projects using ultrasound?

Acoustic Radiation Force Impulse Imaging (ARFI). ARFI is a new technique developed by researchers at Duke University with NIBIB support that uses ultrasound elastography to differentiate liver tumors from healthy tissue, as well as identify the presence of fibrosis. This non-invasive method could reduce unnecessary liver biopsies, which can be painful and sometimes dangerous. Currently, ARFI is undergoing FDA review for eventual use in hospitals and clinics. .

Low-cost, miniature transducers and arrays. By using new transducer materials and new manufacturing methods, ultrasound arrays can be produced in a manner similar to the production of computer chips. One type of new transducer, called CMUTs, are less expensive to produce, easier to manufacture as arrays, and have several advantages over standard transducers. This new CMUT technology was recently used in a device developed using NIBIB funding called the GE V-scanner. The V-scanner is a palm-size ultrasound scanner, which has both anatomical imaging and color Doppler capability. The device is currently in clinical use and costs considerably less than a full-sized ultrasound scanner. Its small size and low cost, as well as range of applications, allow it to be used in ambulances, emergency rooms, field hospitals, or other remote locations. It is currently being used in 100 countries around the world.

Histotripsy technique for dissolving blood clots. With support from NIBIB, researchers at the University of Michigan are investigating the clot-dissolving capabilities of a HIFU ultrasound technique, called histotripsy, for the non-invasive treatment of deep-vein thrombosis (DVT). This technique uses short, high-intensity pulses of ultrasound to cause clot breakdown. The researchers are currently experimenting on pigs, in which they have successfully demonstrated the effectiveness of this technique, and its possible use in humans. This research could have significant impact, since current conventional treatments for DVT involve drug therapy and invasive removal of the clots, which require a 2 or 3-day hospital stay, and may result in complications after treatment. The non-invasive histotripsy technique is 50 times faster than the current technique, and if successful, could be used as an outpatient procedure.

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