Ultrasound is a medical imaging method that uses sound waves to create pictures of structures inside the body. It does not use the kind of radiation found in X-rays or CT scans. The machine sends sound into the body, listens for the returning echoes, and uses a computer to turn those echoes into a moving image.

The word ultrasound means sound with a frequency above the range human ears can hear. Humans generally hear frequencies from about 20 to 20,000 hertz. Medical ultrasound commonly uses frequencies in the millions of hertz, called megahertz. The patient cannot hear these waves because their frequency is far beyond the human hearing range.

The process is similar to an echo. If we shout inside an empty building, sound travels away from us, strikes surfaces, and returns. A nearby wall returns the echo quickly. A distant wall takes longer. A soft curtain absorbs more sound than a hard concrete surface. From the timing and strength of the echo, information about the surroundings can be gathered.

An ultrasound machine does this inside the body at extremely high speed. The handheld part placed against the patient is called a transducer, or probe. Inside the probe are special materials called piezoelectric crystals. When the machine applies electricity, the crystals rapidly change shape and produce sound waves. When echoes return, the same crystals convert those vibrations back into electrical signals.

The probe therefore acts as both the speaker and the microphone. It sends a short pulse, stops, listens for the echo, and repeats the process thousands of times. The computer measures how long each echo takes to return and how strong it is. It then places dots of different brightness on the screen to construct the image.

An echo returning quickly came from something close to the probe. An echo taking longer came from a deeper structure. A strong echo may appear bright, while little or no returning sound appears dark.

Fluid usually appears black or very dark because sound passes through it with relatively few echoes. This makes ultrasound useful for examining fluid-filled structures such as the bladder, gallbladder, certain cysts, blood vessels, and the amniotic fluid surrounding a fetus.

Soft tissues produce different shades of gray. The liver, thyroid, uterus, muscles, and kidneys each have characteristic patterns. Bone and calcified material return strong echoes and may appear bright. Air also strongly disrupts the sound beam, but unlike fluid, air usually prevents the machine from seeing what lies behind it.

This is why the technician places gel on the skin. Tiny amounts of air would otherwise remain between the probe and the body. Air blocks the sound from entering properly. The gel removes that air gap and allows the sound waves to pass smoothly from the probe into the tissue.

The gel does not contain radiation or medication. It is mainly a transmission material. It may feel cold and uncomfortable, but it helps create a clearer image.

Ultrasound images do not look like ordinary photographs because the machine is not using visible light. The picture is a map of returning sound. Learning to read it requires training because normal tissue, abnormal tissue, shadows, fluid, movement, and machine-created distortions can resemble one another.

The person operating the equipment is often a diagnostic medical sonographer. The sonographer must know anatomy, understand how sound behaves, position the patient, select the correct probe, adjust the settings, recognize suspicious findings, and record the images needed by the interpreting doctor.

The sonographer may describe what they are doing, but they often cannot provide the final diagnosis. A radiologist or another qualified physician usually interprets the complete study and sends a report to the healthcare professional who ordered it.

The image changes depending on the frequency used. Higher-frequency sound creates sharper detail but does not travel as deeply into the body. Lower-frequency sound penetrates farther but produces less fine detail.

A high-frequency probe may be used for structures close to the skin, such as the thyroid, testicles, tendons, breast tissue, blood vessels, or a developing fetus early in pregnancy. A lower-frequency probe may be needed to examine deeper organs inside the abdomen or a fetus later in pregnancy.

This creates a tradeoff between detail and depth. The machine cannot simply use the highest possible frequency for every examination because the sound might weaken before reaching the structure being studied.

Ultrasound is especially useful because it displays movement in real time. A regular X-ray captures a moment. Ultrasound can show the heart beating, valves opening, blood flowing, a fetus moving, or a needle entering tissue while the examination is happening.

An abdominal ultrasound may be used to examine the liver, gallbladder, bile ducts, pancreas, kidneys, spleen, abdominal aorta, and other structures. Doctors may use it to look for gallstones, kidney blockage, liver abnormalities, enlarged organs, fluid collections, masses, or an enlarged section of the aorta called an aneurysm.

Preparation depends on the organ being examined. A person may be told not to eat for several hours before an upper-abdominal ultrasound. Eating causes the gallbladder to contract, and gas from digestion can block the view. Fasting may keep the gallbladder expanded and reduce some of the interference.

A pelvic ultrasound can examine the bladder, uterus, ovaries, cervix, prostate, and surrounding tissues. The patient may be instructed to arrive with a full bladder. Fluid inside the bladder creates a useful pathway for the sound and can push bowel gas away from the pelvic organs.

A full bladder may be uncomfortable, especially when the sonographer presses on the lower abdomen, but it can make the examination much more useful. Emptying the bladder too soon may result in poor images or require the patient to drink more water and wait.

Not every ultrasound is performed across the skin. A transvaginal ultrasound uses a narrow covered probe placed inside the vagina. Because the probe is closer to the uterus and ovaries, it can produce more detailed images than an external pelvic examination. It may be used to investigate pelvic pain, abnormal bleeding, infertility, early pregnancy, cysts, or masses.

A transrectal ultrasound places a probe inside the rectum, often to examine the prostate or guide a biopsy. A transesophageal echocardiogram places a specialized probe into the esophagus after medication and numbing are used. Because the esophagus lies close to the heart, this approach can provide detailed images that may not be available through the chest wall.

An ultrasound of the heart is called an echocardiogram. It can show the heart's chambers, valves, muscle contractions, and the direction of blood flow. Doctors use it to investigate heart failure, valve disease, abnormal heart sounds, congenital heart defects, fluid around the heart, and other conditions.

The word ejection fraction may appear in an echocardiogram report. It estimates the percentage of blood pushed out of the heart's main pumping chamber during each contraction. It does not mean the heart should empty completely. A normal heart always retains some blood after it contracts.

A standard ultrasound shows anatomy, but Doppler ultrasound studies movement, especially blood flow. The technique uses the Doppler effect, the same basic reason a siren sounds higher as an ambulance approaches and lower as it moves away.

When ultrasound waves strike moving blood cells, the returning frequency changes. The computer uses that change to estimate the direction and speed of the blood. This can help identify narrowed arteries, blocked vessels, abnormal circulation, aneurysms, or blood clots.

Color Doppler places colors over the ordinary gray image. The colors normally show the direction of blood flow relative to the probe, not whether the blood is "good" or "bad." Red does not always mean artery, and blue does not always mean vein. Depending on the machine's settings, red commonly represents flow toward the probe and blue represents flow away from it.

A vascular ultrasound may be used to look for a deep vein thrombosis, or DVT. This is a blood clot in a deep vein, commonly in the leg. The sonographer presses the probe against sections of the vein to see whether it compresses normally. A vein containing a clot may not collapse as expected. Doppler is then used to evaluate the blood flow.

A suspected DVT requires proper medical evaluation because part of a clot can travel to the lungs and cause a pulmonary embolism. Sudden shortness of breath, chest pain, coughing blood, fainting, or a rapid heart rate can signal an emergency.

During pregnancy, ultrasound can confirm that a pregnancy is located inside the uterus, estimate gestational age, check fetal heart activity, examine fetal anatomy, determine the number of fetuses, assess the placenta, and evaluate growth and amniotic fluid.

An early pregnancy may be examined with a transvaginal probe because the developing structures are still extremely small. Later examinations are more often performed through the abdomen, although a transvaginal study may still be needed for specific questions.

The estimated due date is usually most accurate when based on measurements from an early ultrasound. Later in pregnancy, healthy fetuses naturally vary more in size, so using a late measurement to change the due date can be less accurate.

Ultrasound can detect many fetal abnormalities, but a normal scan cannot guarantee that a baby has no medical or genetic condition. Some conditions cannot be seen with ultrasound. Others develop later, are too subtle to identify, or require genetic testing, MRI, blood testing, or examination after birth.

Three-dimensional ultrasound combines multiple sound images to create the appearance of depth. Four-dimensional ultrasound shows a three-dimensional image changing over time, producing a moving view. These methods may help examine certain fetal features or abnormalities, but they are not automatically medically superior to every standard two-dimensional examination.

Ultrasound is generally considered safe when used properly because it does not expose the patient to ionizing radiation. However, this does not mean the device produces no physical energy. Sound waves can slightly heat tissue, and under certain conditions they can create mechanical effects.

Medical professionals are trained to use enough energy and examination time to obtain the necessary information without unnecessary exposure. Nonmedical “keepsake” fetal scanning and prolonged use of home fetal heartbeat devices are discouraged because untrained users may expose the fetus for too long or misinterpret what they hear.

Finding a heartbeat with a home device does not prove that everything is healthy. Failing to find one does not necessarily mean the pregnancy has ended. The user may detect the mother's pulse, use the device incorrectly, or create unnecessary panic. It can also provide false reassurance when symptoms require medical attention.

Ultrasound has important limitations. Sound travels poorly through air, so ordinary ultrasound cannot provide a complete view through healthy air-filled lungs. It may still detect fluid around the lung, changes near the lung's surface, or certain emergency findings.

Bowel gas can hide abdominal and pelvic structures. Bone blocks the sound beam, preventing an ordinary probe from seeing through the adult skull. Brain ultrasound works well in young infants because openings between the skull bones, called fontanelles, provide a path for the sound.

Large body size may also reduce image quality because the sound must travel through more tissue and becomes weaker before returning. A difficult ultrasound does not mean the sonographer lacks skill or that something is necessarily wrong. The structure may simply be difficult to reach with sound.

Ultrasound is also highly dependent on the operator. The sonographer decides where to place the probe, how to angle it, how much pressure to use, and which images to record. Two exams may look somewhat different depending on the patient's position, the equipment, the operator, and what the doctor is trying to investigate.

A mass discovered on ultrasound is not automatically cancer. The machine may show whether it is solid, fluid-filled, smooth, irregular, well-defined, or connected with increased blood flow. Those features help estimate what it may be, but ultrasound alone cannot always determine exactly what the cells are.

Additional imaging, follow-up studies, blood tests, or a biopsy may be needed. A biopsy removes a sample so the tissue can be examined directly. Ultrasound frequently guides the needle, allowing the doctor to watch its path and avoid nearby blood vessels or organs.

Ultrasound guidance is also used for draining fluid, placing intravenous lines, injecting joints, performing nerve blocks, and examining patients during emergencies. In an emergency department, a rapid bedside examination may search for internal bleeding, fluid around the heart, gallstones, pregnancy complications, or certain causes of shock.

A bedside ultrasound answers focused questions quickly, but it may not replace a complete examination performed by the imaging department. The correct test depends on what the medical team needs to know.

Ultrasound is powerful because it converts something invisible—sound moving through tissue—into information the eyes can study. The probe sends a pulse, the body returns echoes, and the machine builds an image from differences in time, strength, and movement. It can reveal structure and motion without surgery, but its picture is still an interpretation of sound, not a perfect window into the body.