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REVIEW ARTICLE

Technological Evolution of Ultrasound Devices: A Review

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ABSTRACT

Numerous imaging technologies have been researched upon and applied in the field of medicine to enhance clinicians' faculty for diagnosis of indispositions or diseases and the modalities include magnetic resonance imaging (MRI), X-ray imaging, computed tomography (CT) and ultrasound (US). One imaging technique that is used to identify abnormalities in various body areas is the ultrasound. It is a non-invasive method that provides real-time imaging without radiation exposure. This article mainly focuses on ultrasonography and the various technological and equipment advancements over the years. It is more difficult to operate conventional ultrasound equipment due to its complex structure, which is large in size and takes up more space. For scanning different parts of the body, there are a variety of probes to choose from. The probes are selected based on the size and shape of the beam. Imaging can be performed in several modes, such as A mode, B mode, M mode, D mode, etc. Capacitive micro-machined ultrasound transducers (CMUTs) replace the traditional piezoelectric crystals in a transducer that produces ultrasonic waves. Ultrasonography has many applications in the diagnosis of various parts of the body, i.e., lungs, abdominal parts, heart, bladder, and so on. From the earliest ultrasound machines in the 1950s with patient immersion tanks to the hand held ultrasound devices in the late 2000s where images can be obtained on mobile screens, the evolution of this device over centuries has been phenomenal.

Keywords: Ultrasonography, Poly capacitive micro-machined ultrasound transducers, Transducer, Portable handheld ultrasound system.

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INTRODUCTION

Sound is an energy form that is generated by the back and forth movement of the objects, producing vibrations that create the sensation of hearing in the ears. Sound waves are characterized as mechanical waves and do not travel in vacuum, thereby requiring a medium for the movement of particles. Sound generally travels through a medium (solid, liquid, gas) from starting point to the listener's end.[1] The sound waves are characterized by their frequency, amplitude, and speed. The speed of sound in various medium is tabulated below in table 1;

Sound waves based on their frequency ranges are majorly categorized as; Infrasound, Audible Sound and Ultrasound waves. Normal audible range for humans is between 20Hz and 20KHz. It is possible for children to hear up to 25KHz in their early years, but their ability to hear higher frequencies declines as they grow. Frequency ranges of sound is tablulated in table 2.

Definition of Ultrasound:[1,2]

Ultrasound waves are higher frequency waves that are not audible and are reflected by obstacles. For medical diagnosis and procedures, ultrasound is a well-known imaging technique that is frequently used. It is the one technology that has evolved by taking significant challenges and opportunities. With its portability, affordability, and improving technology, ultrasound is now the most commonly used imaging modality by emergency physicians. This imaging technique is non-destructive and versatile and can provide high image quality.[3]

In contrast to X-rays, CT scans, and MRI scans, ultrasound is a radiation-free and non-invasive diagnostic imaging tool. It promotes real-time imaging[4] capabilities, accessibility, safety at a comparatively low cost in comparison to techniques like X-rays, CT, MRI, and Positron Emission Tomography (PET). Due to these features, medical ultrasonography has become a

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Table 1: Speed of sound in different mediums [1]

Medium	*Speed of sound*
Air	330m/s
Fat, water	1400 m/s
Soft tissues	1540 m/s
Muscle, cartilage, tendon	1700 m/s
Very high	3500m/s

Table 2: Different ranges of sound along with frequencies [2]

Sound	*Frequency*	*Audible to*
Infrasound	<20 Hz	Rhinoceroses, whales, elephants
Audible sound	20-20,000 Hz	Humans
Ultrasound	>20,000 Hz	Dolphins, bats
Non-diagnostic medical applications	<1 MHz	-

favoured imaging modality, not only in established contexts like emergency departments[5] and critical care units,[6] but also in more recent settings including cardiology, general imaging, and obstetrics/gynecology. Medical ultrasound is a vital technique in biomedical engineering due to its many benefits, including safety, affordability, and ease.[7] Depending on its strength, ultrasonography can detect a variety of physical traits. For instance, thermal effect produced by high-intensity ultrasound can be helpful in the treatment of cancer.[7,8] The ultrasonic wave's interaction with tissue is influenced by a number of factors (such as absorption or the creation of cavitation bubbles), which results in bio-effects like heating or mechanical destruction and creates various transition zones. A well-known emerging physical technique that will make it easier to deliver drugs and genes to living cells is the use of ultrasound combined with cavitation nuclei to pierce plasma membranes.[9]

Recent developments in ultrasound technology, array types, and transducer materials are discussed in this review along with their numerous medical uses. The characteristics and origin of ultrasonic waves are covered in the first part. The probe types and generations of ultrasound equipment are discussed in the sections that follow with brief description of several uses for ultrasound in different industries, including medical and drug delivery.

Properties of ultrasound[10]

Ultrasonic waves are sound waves with a frequency greater than 20 kHz.

- The frequency of the ultrasound waves are higher than what humans can hear.
- As ultrasonic waves travel longitudinally, they compress and rarefy alternately
- Capable of travelling in well-defined paths even in the face of impediments
- These waves move through a medium at the speed of sound, or at their highest velocity in denser media
- These waves generate heat while passing through the objects

Source of ultrasound

Ultrasound waves are generally produced by using piezoelectric crystals made of piezoelectric materials like:

- Lead Zirconium Titanate (PZT)
- Quartz crystals
- Oxide lead zirconate titanate
- Lithium niobate
- Poly CMUTs is the latest one

Poly CMUT[11]

The tiny vibrating drums composed of polymer resin known as poly CMUTs were used in place of the piezoelectric crystals.[12] Figure 1 depicts a transducer fabricated using polymer-resin drums. In addition to having a broad frequency range, CMUTs are also simple to build in a wide size ranges, shapes, and frequencies using 1D and 2D array topologies. These can be manufactured in a more affordable manner and are adaptable and need 10 volts to function.

Working Principle of Ultrasound

Piezoelectric materials are electro-mechanical transducers that produce ultrasound. In response to an electric field, these materials undergo deformation by contracting and expanding due to the potential changes that cause mechanical vibrations, and vice-versa (converting mechanical vibrations to electrical vibrations).

CMUTs use oscillating drums embedded in silicone chips to transform power into sound waves instead of vibrating piezoelectric crystals.[12] In CMUTs, a vacuum gap connects a thin membrane to a conductive substrate, creating a capacitor. By applying voltage to the thin membrane, which serves as a drum, ultrasound vibrations are produced.

The thin membrane vibrates in response to acoustic waves that are reflected back from tissues, producing an electric signal.[13] The inadequate imaging quality of handheld ultrasound instruments, which lowers diagnostic accuracy, has been a concern.[14] Ultrasound frequency directly correlates to resolution; greater the frequency, better the resolution. To summarize, acoustic waves are transmitted by the transducer,

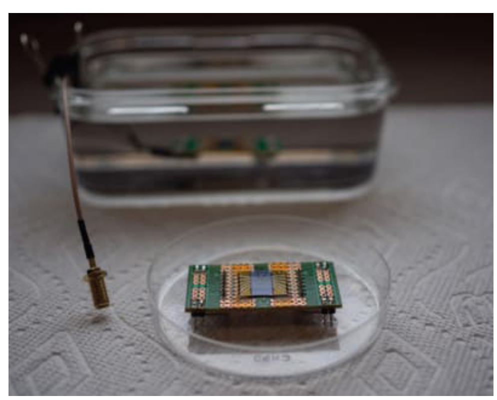

Figure 1: Transducer fabricated using polymer-resin drums[11]

which gets reflected off a body part they reach. Reflected waves are received and analyzed by the transducer and lastly, the results are processed and displayed.

2.1 Components of ultrasound[15]

The core components of an ultrasound imaging system are the transmitter module, receiver module, control, display and power supply module.[16] The various parts of ultrasound are as follows:

- Transducer (transmitter, probe, and receiver)
- Processing unit
- Display

Transducer

A transducer, also known as a probe, is the primary component of an ultrasound system. It contains a crystal formed of piezoelectric material, which produces ultrasonic waves by the converse piezoelectric effect (conversion of electrical energy into mechanical (sound) energy and vice versa). They can thus function as ultrasonic transmitters and receivers. The lens, backing layer (which latches to the crystal's back and attenuates ultrasonic signals that come from the housing), piezoelectric material (crystal consists of a single element or multiple elements in which a thicker element produces lower frequency oscillations and a thinner or finer element produces oscillations of a higher frequency), matching layer (it interfaces between the tissue and the transducer element, thereby minimizes the reflection) and housing (insulator to protect the crystal).[17]

Pulser

The voltage produced by the pulser powers the transducer. The beam will be produced with a specific strength and intensity depending on the applied voltage, which will impact the brightness of the image as a whole.

Beam-former

The ultrasonic signal is sent from an array with the help of a beam-former, which also regulates the ultrasound beam's direction, shape, and scanning patterns. By employing beam-formers the operator can indirectly control:

- Depth
- Focus
- Sector width
- Zoom

Processor

The processing unit consists of Analog Front End (AFE) and digital processing for both the front and rear ends (using micro-controller or FPGA). The processor may execute many functions as both a signal and an image processor. The processing front end has a low noise amplifier (LNA, which amplifies the signal with a low signal-to-noise ratio), variable gain amplifier (VGA, an equalizer that equalizes the low or high signals to the same level), an analog to digital converter (ADC, analyzes the signals digitally). A time-gain compensation function can be used to account for the attenuation caused by depth.

Signal processor - Derives video signals from echo voltages.

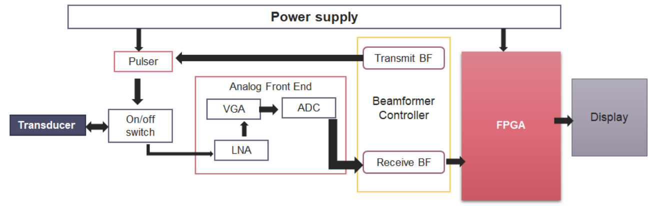

Figure 2: Block diagram of the ultrasound system

Image processor - The numerous scan line data are formatted into images by an image processor.

Filtering - Signals are cleaned up by filtering, which also limits the bandwidth of the signal and eliminates unwanted noise.

Display

Images processed are displayed on a flat panel screen or computer monitor and are stored as both soft and hard copies.

A power supply of high voltage (HV) is needed in the transmitter component of an ultrasound imaging system, while a low voltage (LV) power supply is needed in the receiver section. Figure 2 below represents an ultrasound system's workflow;

Literature Review

At the patient's bedside, a comparison of portable and high-end ultrasound machine was made, and it was found that portable ultrasound takes less examination time than a high-end machine. When compared to superior ultrasound devices, portable ultrasonography is limited in its capacity to detect a number of ailments.[18] The numerous uses for various ultrasound scanners, including conventional, table-top or portable, and pocket-sized handheld ultrasound scanners, as well as the use and necessity for handheld scanners, along with the specifications and advantages, were discussed.[19]

It was investigated if handheld ultrasonography could be used for abdominal and pleural applications, however more research was required, to gather sufficient data.[20] In order to monitor COVID-19 patients, many probe technologies, including piezoelectric crystals (PZT), PMUT, and CMUT, were used. During the pandemic, it was discovered that these technologies had advantages in medical diagnostics.[21]

Delores Jones described how POCUS (Point of Care Ultrasound) helps to shorten patient wait times by enabling radiologists to view diagnostic images instantly by a medical professional to assist in determining what is causing specific medical symptoms in patients.[22] In anesthesiology and other medical specialties, the POCUS system has gained popularity. These specialties now provide courses that cover training, certification, and the use of three handheld ultrasound probes (Philips Lumify). A CMUT microprocessor is utilized in other multi-functional handheld devices, like the Butterfly iQ, which does not use a piezoelectric crystal.[23]

Due to the patient's precarious health, the cardiologists conducted a POCUS evaluation utilizing the Butterfly iQ HHU device connected to the phone (iPhone SE pro-Butterfly iQ software) in order to detect any abrupt onset of respiratory distress or tachycardia.[24]

According to A.N. Malik et al., hand-held medical devices are being quickly adopted by doctors working in emergency rooms because to their affordability and convenience, but their use is constrained by their limited capabilities in comparison to cart-based systems. The authors of this study found that HHU had some drawbacks compared to cart-based systems, including photo storage and frequent overheating. The advantages of HHU included; a decreased requirement for follow-up testing, low frequency of erroneous findings, and quick diagnosis.[12]

The fabrication processes for Capacitive Micromachined Ultrasonic Transducers (CMUT) on Complementary Metal Oxide Semiconductor (CMOS) were elucidated by M. S. Salim et al., along with the original usage of MEMS (microelectromechanical systems) technology and subsequent use of CMUTs.[25,12] To minimize layout and board size, the high voltage pulse driving circuit was designed to be entirely integrated with the CMOS circuit.[26]

The study "Custom Integrated Circuit Design for Portable Ultrasound Scanners" by Limos Muntal and Pere concentrated on the integrated part of electronic designs, which were demonstrated and evaluated by fabricating three prototypes, namely, Integrated Circuits, ASIC0, ASIC1, and ASIC2. This evaluation was done by taking into account the area (PCB) and power consumption of portable ultrasound system, as well as various parameters related to transmitting and receiving channels.[27]

The numerous developments in medical ultrasound systems were comprehended through the literature studies, and the latest development of the CMUT chip by substituting the piezoelectric materials in the probe was also examined. The portable ultrasound devices that are now on the market have benefits and drawbacks. For instance, Butterfly iQ+ features a three-in-one probe but has poor cardiac picture quality and huge footprints,[28] in addition to other issues including EMR (electronic medical record) integration, high loading times, frequent overheating, and other parameters that were restricting its applications.[29]

Ultrasound Device Evolution[30,18]

In 1794, Italian physiologist Lezzaro Spallanzani made the first inference that bats used ultrasound to navigate in complete darkness by reflecting high-frequency noises or echolocation. Later, this served as the foundation for ultrasonic physics.

In 1826, by submerging a church bell in Lake Geneva, Swiss physicist Jean-Daniel Colladon measured the sound speed. Colladon discovered that water conducts sound more quickly than air.

After the Titanic crashed in 1912, a French physicist named Paul Langevin had the notion to develop an ultrasonic gadget that could spot or detect icebergs. The first technological application of ultrasound (Hydrophone) was made by Paul Langevin and Constantin Chilowsky to spot submarines (Hydrophone). In World War 1, submarines were also detected with these hydrophones.

In 1942 using ultrasonic rays that travel through the head, Karl Theodore Dussik, an Austrian psychiatrist and neurologist at the University of Vienna, diagnosed brain cancers also known as hyperphonography. As the pioneer in the field of diagnostic ultrasonography, Dussik created a device in 1947 that employed heat-sensitive paper to record the echoes of ultrasonic transmissions to generate images of the brain and ventricles. These pictures were known as *ventriculograms*.

In 1949, an American radiologist named Douglass Howry created a pulse-echo ultrasonic scanner from radio store spare components and Air Force obsolete radar equipment. Howry took images of the ultrasound with a 35mm camera and recorded them a year later. Later in 1951, Douglass Howry created a B-mode linear compound ultrasonic scanner with transducers, amplifiers, and display imaging with the aid of American nephrologist Joseph Holmes. Compound scanning was a technique used by Howry and his team to eliminate false echoes. Howry was able to distinguish between structures and tissues using compound scanning, which led to improved imaging results known as *somagrams.*

In 1952, the American Institute of Ultrasound in Medicine (AIUM) was established, and in 1953 Swedish physician Inge Edler and engineer Carl Hellmuth Hertz successfully performed the first echocardiography to identify mitral stenosis.

In 1955, doppler shift techniques were used by Japanese scientist Shigeo Satomura and his team to measure the heart's and other blood vessels' pulsations. The Doppler Effect was used for the first time in a medical setting.

The Pan Scanner was unveiled in 1957. In order to detect a regulated sound beam, the transducer revolved semi-circularly around the patient without submersion as opposed to the previous technologies where the patients had to be submerged in water entirely.

In 1958, Ian Donald published Investigation of Abdominal Masses by Pulsed Ultrasound in the medical journal The Lancet. OB-GYN ultrasound was given a father figure in Ian Donald. Donald used ultrasound to find cysts and tumours in his abdomen and later used it to find a twin pregnancy.

In 1962, a new compound contact scanner was created by Joseph Holmes, William Wright, and Ralph Meyerdirk. It made use of wire mechanisms and electrical position transducing potentiometers. The transducer was the first of its kind to be positioned by hand.

The first hand-held compound contact B-Mode scanner was introduced for sale in the US in 1963. This marked the start of the most widely used ultrasonic scanner design.

In 1972, the first commercial linear array scanner was created by famous cardiologist Paul Hugenholtz and Organon Teknika, a Dutch business. This scanner was known as the "Multiscan System."

In order to create high resolution real-time sectoral images, James Griffith and Walter Henry develop an oscillating real-time scanning apparatus in 1973. One of the most important advancements in sonography was said to be this 2D scanning gadget.

In 1975, a 128-point multi-gated pulsed Doppler device was used by Marco Brandestini and his team at the University of Washington to capture images of blood flow. The color-coded ultrasound pictures were placed on 2D anatomical representations.

The year 1976 saw the creation of one of the earliest digital scan converters with memory by Albert Waxman and his colleagues. Analog systems were being replaced by digital scan converters.

During the 1980s the United States experienced rapid growth in POCUS, 3D ultrasound, and Power Doppler. In 1987 the real-time 3D volumetric scanner for visualising the cardiac structures were developed by Duke University's Center for Emerging Cardiovascular Technologies, led by Olaf von Ramm.

In 1994, a better scanner with great resolution down to 20 cm was created by Olaf von Ramm and Stephen William Smith of Duke University. Modern medical ultrasound imaging integrated circuits (MUsIC) that could process signals from numerous real-time phased-array images were created by the duo and their team.

In 1996, using sonographic cardiac gating techniques to eliminate motion artefacts, which were frequently present with static 3D methods, Thomas Nelson and his team published independent investigations on 4D (motion 3D) foetal echocardiography in 1996. The first POCUS fellowship was formed in Chicago in 1997.

Guidelines for the use of POCUS in practise and other disciplines were published by the American College of Emerging Physicians (AGEP) in 2001.

Standard ultrasound systems are large and thereby take up more room. It is recommended that these systems are kept in a designated location and not moved around often. It has numerous probes attached to a single device that can be utilized for various diagnosis. Figure 3 is an example of such standard ultrasound systems with multiple probes.

Portable ultrasound devices have been on the market for a while, numerous studies have been conducted to determine their utility. Due to their compact size, portability, and ability to be operated both remotely and on a tabletop, these devices are easily transported. There are several portable ultrasound devices on the market such as, GE Ultrasound, Siemens Ultrasound, Sonosite Micromax and many more.

Figure 4: Portable Ultrasound System

Handheld ultrasound systems are smaller and more economical ultrasound machines have been developed as a result of the typical ultrasound machine's bulky and expensive design as well as the fact that rapid access to an ultrasound facility is not always feasible.[31] Figure 4 depicts a portable ultrasound system. Since they are smaller in size, these new ultraportable devices can be kept in hands or pockets. Conventional ultrasound equipment cannot be employed in point-of-care (POC) applications due to their large form factors. A POC is a type of care given to patients at their bedside. When dealing with ambulances, military circumstances, accidents, rural health care, etc., it is incredibly beneficial. Ultrasound scanning for point-of-care (POC) applications only needs a minimal setup thanks to developments in computing platforms.[32]

Various handheld ultrasound machines available in the market are:

- Butterfly iQ+
- V scan Air
- Claris HD
- Double probe wireless handheld ultrasound scanner and many more

In order to provide a better scanning experience, handheld ultrasound equipment have been continuously improved in terms of picture quality and performance. Figure 5 demonstrates the technological advancements in the use of portable ultrasonography over time in different nations.[33] Considering that HHU (handheld ultrasound) technologies provide affordable, secure, and reliable diagnosis and treatment

Figure 3: Standard Ultrasound Systems with multiple probes

[Images Courtesy: pexels.com]

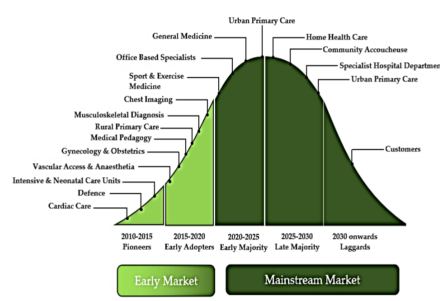

Figure 5: Graphical representation of technological advancements in ultrasound diagnosis

Table 3: Comparison of various HHU [25]

Name	*Probes*	*Wireless*	*Cost (approximate)*	*Display*	*Storage*
SonoSite iViz	Linear, curvilinear, phased array	No	>$10,000; no subscription	Proprietary tablet	DICOM & cloud capable
Butterfly iQ+	CMUT probe	No	$1,999 with $420 annual subscription	Cloud-based; DICOM capable	Personal iOS or Android smart device
GE Vscan	Sector, dual-head linear/sector, dual-head linear/ curvilinear	No (VScan Extend) Yes (VScan Air)	$2,995-$4,995; no subscription	**Extend:** Proprietary tablet **Air:** Personal iOS or Android smart device	On-device or cloud; DICOM capable
Philips Lumify	Linear, curvilinear, phased array	No	$6,000; no subscription	On-device; DICOM capable	Personal Android smart devices, iOS devices with an adapter
Clarius	Linear, curvilinear, microconvex & endocavity	Yes	$4,900-$6,900; no subscription	Cloud-based; DICOM capable	Personal iOS or Android smart device

alternatives, it is anticipated that their use would rise during the projection period.

Recently, a variety of reasonably priced mobile gadgets with the promise of diagnostic quality images captured using current smartphones or exclusive tablets have entered the market.[34] and table 3 compares various handheld ultrasound devices available in the market.

Comparison of various handheld ultrasound devices are tabulated below:

Types of Transducer Probes

In general, the footprint, frequency, and piezoelectric crystal configuration of the various probe types vary. The part of the body that makes contact with the body's surface and leaves a footprint is in diverse sizes and shapes. The piezoelectric crystal arrangement used to create the image determines the shape and size of the image.

The ultrasound beam is produced in two ways:

- Sequential array
  The shape of the image is identical on top and bottom of the image.
  Ex. Linear array, micro-convex array
- Phased array

The shapes are distinct i.e. curved at the bottom and rectangular at the top of the image. Table 4 compares features such as footprint, image depth and so on of various probe arrays.

Specialized probes[36]

Endocavity probes are one type of specialized probe that are made for particular body orifices. Images of the heart are produced by transesophageal echocardiogram (TEE) probes (3-10MHz) through the oesophagus. Blood flow and speed are measured with pencil probes, commonly known as CW Doppler probes (2-8MHz).

5.1 Modes of ultrasound[37]

An ultrasound system has several display options, including amplitude (A-mode), brightness (B-mode), motion (M-mode), Doppler (D-mode), and 3D mode. One pulse is acquired in the A mode (the body is scanned by a single transducer, and the echoes are plotted on the screen as a function of depth.). It displays time-dependent one-dimensional maps of the direct amplitudes of received echoes.

The B mode is the most commonly used in which the signals received were rapidly processed to form a grayscale image. High reflection waves appear as whiter (brighter) echoes whereas less scattered waves are darker in 2D or 3D view. Motion imaging is used for studying moving structures like heart walls or valvular movement. The images in this mode are displayed as a continuous function of time as depth vs time.

Doppler imaging is primarily employed to quantify and depict blood flow. The images are color-encoded and placed on a grayscale B mode image in colour doppler mode. Color Doppler ultrasound can be used to distinguish between vascularized and non-vascularized tissues.[8]

The Doppler frequency shift within a previously chosen region of interest can be shown as a function of time using spectral Doppler imaging. 14 plane wave pulses delivered at an angle of 12 degrees and a repetition rate of 3 kHz were used to acquire Doppler ultrasound data.[4] Three full cycles of transmission pulses, as opposed to one for B-mode, were used for acquisition to boost Doppler sensitivity.

Applications of Ultrasound

Ultrasound radiation force can be used for a number of therapeutic purposes, such as manipulating cells and/or particles, delivering medications, and regulating brain activity. US fusion imaging benefits from the wide field of view and high contrast resolution of the other imaging techniques as well as the spatial resolution and dynamic information of the standard US in real time.[38]

- Ultrasound waves are employed to identify object faults (cracks and flaws in metal blocks)
- Used in echocardiography
- Used in the diagnosis of pathological conditions in various organs. Through ultrasound imaging, structural anomalies, cysts, stones, malignancies, congenital malformations, edoema, and obstructions of the urine flow can be estimated and found.[39]
- Used in imaging of gall bladder stones and kidney stones
- Used in imaging of other organs such as lungs,[40] liver, abdomen, and bladder

Table 4: Features of various probe arrays [36]

Features	*Linear array*	*Curvilinear*	*Phased array*
Frequency range	High, 5-10 MHz	Low, 2-5 MHz	Low, 1-5 MHz
Image depth	9 cm	30 cm	35 cm
Footprint	Relatively large	Large	Quite small
Beam shape	Rectangular	Convex	Narrow & almost triangular beam points
Scan	General imaging, vascular, arteries, veins, skin, eyes, breast	Liver, kidney, bladder, abdominal, gall bladder, OB/GYN, vascular	Heart, lungs, abdominal, brain

- Used to assist doctors in evaluating symptoms such pain, swelling, infection, and haematuria

It is beneficial for examining several internal organs, including but not limited to: the heart[41] and blood vessels, lung,[42] gall bladder, liver, pancreas, spleen, kidneys,[43] bladder, uterus, eyes (ophthalmic ultrasound imaging), thyroid, brain, ovaries, and unborn (foetus) in pregnant patients.

- Used in breast imaging and to guide physicians in breast cancer biopsy
- Used to perform needle biopsies, in which sample cells are extracted using needles.
- Ultrasound is an efficient imaging technique for assessing the musculoskeletal system, including the tendons, muscles, and ligaments, is ultrasound.[44]
- Depending on the transducer geometry and central frequency, High-Intensity Focused Ultrasound (HIFU) causes an area of coagulative necrosis near to the focal spot region
- Large molecules can more easily pass the scleral barrier with Moderate Intensity Focused Ultrasound (MIFU) therapy.[45]
- The optimal plane for needle insertion can be determined using a Doppler US, as well as the major vessels (such as the hepatic arteries, portal vein branches, and hepatic veins) that must be avoided
- Two therapeutic US techniques that have been studied for the treatment of cardiac arrhythmias and ischemic heart disease are high-intensity focused ultrasound and extracorporeal shock wave therapy.[46]
- Ultrasound is the recommended imaging technique for evaluating the kidney stones.[48]
- A lung ultrasound may help in locating and keeping track of an infection if COVID-19 is suspected.[47]
- Lung ultrasound is superior to bedside chest X-rays and comparable to chest CTs for various pleural and lung diseases.[48,49]
- Intravascular Ultrasound (IVUS) imaging is a useful technique in the identification of cardiovascular disorders, according to numerous studies. By directly imaging the vessel wall, IVUS can measure the lumen size, plaque features, and calcium levels
- High-frequency optoacoustic waves can be produced to perform optoacoustic cavitation, which is useful for controlling medication release. Ultrasound produced by a laser is a new technique for neuromodulation

CONCLUSION

The capabilities of medical ultrasound devices have revolutionized recently, along with their skyrocketed accessibility and utilization. The rapid advancement of ultrasound technology is broadening its global impact beyond anything that could have been imagined even a few years ago, from remarkably detailed three-dimensional pictures of the heart and other internal organs to the accessibility of fundamental two-dimensional imaging in far-off communities.[50] General practitioners have typically had limited access to basic tools like stethoscopes, whereas specialists have had heavy access to a variety of high-tech medical tools that are exclusively available in hospitals. However, because general practitioners can now use affordable, high-quality, and light-armed technologies like portable handheld ultrasound devices, medical practise has changed rapidly. It is necessary to develop a world-class operating education system and platform in order to enhance the skills of medical and non-medical staff when using US devices. The development of this technology over the years has been astounding, starting with the first ultrasound machines in the 1950s that used patient immersion tanks and ending with handheld ultrasound devices in the late 2000s that allow images to be viewed on mobile screens. Images from the screen of early ultrasound devices were captured using open-shutter photography. Various still photos of moving objects were recorded, successively exhibited, and deciphered by attempting to perceive the objects in motion.[51] With the creation of more complex transducers and improvements in image quality, ultrasound technology continued to advance during the 1970s and 1980s. Point-of-care ultrasonography has been practised in almost all specialties since the 1990s. By the 2000s, ultrasound technology had evolved significantly, and three-dimensional ultrasound had been developed for some diagnostic applications. However, two-dimensional ultrasound has continued to be the norm for the majority of cases. The continual reduction in the size and cost of ultrasound devices during the 2000s was a significant change as opposed to the previous ultrasound machines that were bulkier, expensive and took more time for image generation and diagnosis. Ultrasound use by all providers has expanded exponentially as a result of ultrasound instruments' increased portability and cost.

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