Applications of Ultrasound in Medical Diagnosis

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Abstract

Ultrasound is a sound energy emanating from vibrating body with frequency between 20 hertz – 20000 hertz. Ultrasound possesses wide applications in industry and medical field. Ultrasound devices are frequently used in medical diagnosis without any radiation exposure to the patients. These devices consist of a transmitter and a receiver (called transducer), pulse generator, amplifiers, the control unit for focusing, digital processors and a display screen. It plays a vital role in the examination of abdominal, cardiac, maternity, gynecological, urological and cerebrovascular, breast, pediatric and preoperational planning and post-operational surveillance. The major applications of ultrasound in medical diagnosis are emphasized in this paper.

Introduction

The term "ultrasound" implies sound energy above human audible range, (>20,000 hertz). A simple sonographic scanner operates in the frequency range of 2 to 18 megahertz which is hundred times greater than the audible range of human being. The frequency and the wavelength are inversely proportional, higher frequencies have shorter wavelength. Sonography is a technique to illuminate images of the internal body organs, tendons, muscles and joints. Sonographers use ultrasound probe for examination that is placed on the patient or moved over the patient for the medical diagnosis. Ultrasound scanning is much cheaper than CT-scans and MRI scans and no side effects.[1-9]

During World War I (1917), Langevin used an echo sounding device to detect the submarines which is the first practical application of ultrasound. In late 1950's, the application of ultrasound has emerged in medical field. It is introduced in the obstetrics, and after that in all the medical fields (3). The ultrasound diagnosis is a valuable tool from the clinical point of view because of its noninvasive, precise visualization and easy to handle (4, 5). Initially, B-mode sonography is widely accepted method. A quiet lot of improvement in image resolution is obtained with the transducer development. Two different techniques are mainly implemented in the ultrasound diagnostics (2), transmission and reflection. Transmission technology is used to differentiate different tissues by absorbance of ultrasound. Based on the lighter and darker regions of the internal structure, the anomalous absorption of ultrasound images are generated (1,6). The reflection technology is based on SONAR (Sound Navigation and Ranging) principle, which registers the pulse reflected from the boundary of two different tissues. The reflection technology is in use but the transmission technology is abandoned.

The Characteristic Features of Ultrasound

Ultrasonic waves are highly energetic sound waves of frequency above the audible range of human ear, (frequency > 20 kHz) e.g., bat sound, dolphin sound and dog whistle. Waves are described by four important parameters and they are Wavelength, Frequency, Velocity and Intensity[17-24]

These parameters are related by the formula:

$v = f\lambda$

v–Velocity of ultrasound (approximately 1540 m/s in the soft tissues),

f–Frequency in Hz

λ–Wavelength in m

In medical diagnostics, ultrasound is used as short pulses with frequency between 3 and 10 MHz. Similar to light waves, ultrasound waves undergoes reflection, refraction, scattering and absorption of energy. The human tissues vary significantly and observed to be non-homogeneous. The passage of ultrasound waves through the human tissues leads to reflection, refraction and scattering, due to non-homogeneity.

Reflection depends on the characteristic acoustic impedance of the funds on whose border is reflected ultrasound. The higher frequency enhances the absorption and refraction of ultrasound waves compared to lower frequency. Therefore, a frequency of 3 MHZ is used for liver, kidney and pancreases examinations, whereas for examination of children, neck and breastaround 5 MHz ultrasound is used, and sometimes even 7 MHz. The higher frequency deciphers the internal parts in detail with high resolution.

Different Scan modes

Ultrasound scan modes are classified as

- A-mode or Amplitude mode display: A single transducer is used to transmit and receive the pulses in a one dimensional line through the body with the echoes plotted on screen as a function of penetration depth.
- B-mode or Brightness mode display: The transducer is moved rather than fixed which can scans a plane through the body and viewed as a two-dimensional image on screen.
- T.M.-mode or Time-Motion mode or C-Mode: A successive display of B scan mode whose images are displayed in sequence on screen as a video. This can be used to identify the motion of internal organs, as the organ boundaries that produce reflections move relative to the probe.

Ultrasound machine and probes

A simple and compact ultrasound machine is made up of transducer probe, pulse generator, Central Processing Unit, amplifiers, monitor for display, keyboard, data storage and printers. The important component of the ultrasonic machine is the ultrasonic probe or transducer which transmits and receives ultrasonic waves. It consists of acoustic lens, match layer, piezoelectric element (PZT) and backing material. The lens is mainly used to focus the internal organs of the patient and the match layer prevents the large acoustic impedance created from the transmitted and reflected signals. PZT is connected to external voltage and produces ultrasonic waves, whereas the backing material converts the continuous ultrasonic waves to short pulses. Several types of probes are present in the medical diagnosis but the linear probe is the widely used tool as it covers large body space.

Doppler Effect

When there is relative motion between the sounding body (source) and a listener (receiver), the pitch of the note heard by the receiver is altered. This phenomenon is called Doppler effect. If the receiver approaches towards the transmitter, then the frequency is higher than the emitter one. Similarly the receiver moves away from the transmitter then the frequency is lower than the emitted one. Here the difference between the received and transmitted frequency is known to be Doppler shift (GlicicLj, 1981). It is widely used in medical field, especially diagnosis. Ultrasound scanners transmit sound energy as short pulses inside the body and the detector receives the reflected sound from the internal parts of the patient.

Ultrasound diagnosis in Pregnancy

First Trimester:

With the recent development and technology, the ultrasound diagnosis is observed to be a powerful and quiet often used technique in pregnancy. A pregnancy confirmation with a 3 – 4mm gestational sac can be seen with a transvaginal probe by 5 weeks from the last menstrual period. Similarly multiple gestational sac can be identified within the uterus. Threatened abortion and completed abortion or ectopic pregnancy can be concluded using ultrasound diagnosis during the first trimester of pregnancy. In addition, uterus abnormalities or malignancy can be identified using ultrasound diagnosis.

Second trimester:

The physical features of the baby, baby's head, brain, arms, legs, spine, limbs and abdomen can be measured using ultrasound scanning. The amount of amniotic fluid around the baby can be assessed. The heartbeat of the baby can be examined as usual as an adult
120-180 /minute. The gender of the baby can be determined during 18-20 weeks. The location of the placenta is checked in second trimester.

Third trimester:

During trimester, ultrasound scan is performed after 30 weeks to check that the baby's continuous growth rate is normal. The position of the baby is detected such as head down, bottom down or baby lying across the uterus. The clear images of the baby, especially baby's face, are often seen on this third trimester ultrasound. The fetal movement and the heart beat can be checked with the ultrasound diagnosis using Doppler shift. Here the location of the placenta is monitored to make sure that's not blocking the cervix.

Limitation of ultrasound diagnosis:

Ultrasound cannot detect all abnormalities and also cannot guarantee that the baby will not develop any complication during pregnancy. The abnormalities like autism, cerebral palsy or learning difficulties cannot be detected using ultrasound diagnosis as these anomalies are not related to structural parts of the baby.

Some other applications of Ultrasound

Endoscopic ultrasound:

A long flexible tube attached with a light and a micro camera is passed through the mouth into the stomach to investigate esophagus, stomach, small bowl, gallbladder, bile duct and abdomen. In addition, it is used to examine the lymph nodes in the chest.

Rectal ultrasound:

A small ultrasound microphone is used as a probe to investigate the prostate glands. The ultrasound scans are used to identify the tumors present in the various internal organs of the body.

Colour Doppler:

Colour Doppler imaging is mainly used to investigate the direction of blood flow and its velocity. In specific, a 2D and 3D echocardiography is used to investigate the cardiac valves and cardio vascular functions by mean blood flow velocity. If the blood flows towards the transducer, then colour is coded as red and if the blood flows away from the probe, then it is coded as blue. Moreover, the slower velocities of the blood flow are represented by dark colours and faster velocities are shown as light colours.

Kidney stone removal:

Ultrasound energy is efficiently used in the removal of kidney stone and this has been proven clinically (9). The ultrasonic waves are transmitted to and absorbed by the stone, which are fragmented into small granules or powder. These tiny particles are evacuated through the nephroscope and suctioned through the probe.

Sonography can be used to examine the internal organs like kidneys, liver, bladder, gallbladder, thyroid, spleen, pancreas, scrotum, uterus and ovaries. Eventually, the ultrasound scans play a crucial role in medical diagnosis, especially to identify the defects in heart valves and tumors present in the various internal organs of the body.

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