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# Ultrasound and its medical applications

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## Introduction

Other names for ultrasound imaging are sonography or ultrasonography. During the examination gel is placed directly on the part of the body, a probe is inserted and the air pocket of the probe is pressed against it. The probe sends high frequency sound waves through the gel into the body. The transducer device converts the sound waves into electrical signals. These signals are used by a computer program to transfer the measured data into an image. During ultrasonography examination, a possible harmful radiation arises. Structures and movements of the organs located in the examined area can be transmitted to the examiners screen in real time. For example, the blood flow through veins, the movements of the contracting heart in M-mode and especially fluids in body cavities are clearly visible. For this reason, the noninvasive technique of sonography supports the physician in processes of diagnosis and treatment of medical conditions. Computerized ultrasonography devices produce images of the body that show thin and flat sections. Nowadays even three-dimensional imaging is possible. Furthermore special sound techniques like the Doppler ultrasound allow the evaluation of movements of fluids in the body. As a result of this cardiologists or specialists for vascular surgery can detect stenoses in arteries and veins, to prevent strokes, e.g. the carotid artery is controlled to detect possible deposits.

### Types of Doppler ultrasound

With the so-called Color Doppler measurements of the blood flow can be transferred into a colored picture that shows the speed and direction of blood flow through a vessel. The third type of Doppler ultrasound displays the measurements in graphics. All images are displayed on a color table. These tables indicate the distance traveled per unit of time. Moreover the data can be converted into a characteristic sound that develops during heartbeats.

## Importance in clinical medicine

Ultrasonography examinations are a very useful technique to diagnose and monitor a variety of conditions as well as pathophysiological changes in organs. Ultrasonography technology enables doctors to assess symptoms like infections, pain, and swelling.

The following internal organs can be examined by ultrasound: heart and blood vessels, including the abdominal aorta and its major branches, liver, gallbladder, spleen, pancreas, kidneys, bladder, uterus, ovaries, and unborn child (fetus) in pregnant women, eyes, thyroid and parathyroid glands, scrotopus (testicles), brain in infants (during the fontanelles), hips in infants, spine in infants. In some cases ultrasonography plays an important role in the guide procedures the needle insertion and after applying control measures catheters. Needle biopsies are in some cases necessary to distinguish between malignant and benign tumors. Diagnostic ultrasound examinations require ultrasonography imaging to detect breast cancer.

The sonography enables the doctor to identify a huge variety of cardiac diseases like congenital heart failures or valve problems, and to evaluate the measures of damage after a heart attack. The name for ultrasonography examinations of the heart in medical literature is called echocardiography. The Doppler Sonography another term for Doppler ultrasound helps physicians to detect stenoses caused by blood clots or fat residues that lead to blockages of blood flow. As a follow-up, narrowed vessels can cause or reduce or missing blood supply of vital organs. Also an increased blood flow can indicate inflammatory processes inside the body. These kinds of examinations helps the doctors to decide whether a patient would benefit from an angioplasty procedure. This is a non-surgical method of dilating and reopening of a stenosed blood vessel by stent implantation. A balloon inserted in the closed vessel brings it to a normal shape and it is thereby dilated the vessel.

## Literature review

As ultrasonography examinations are used in a broad spectrum of medical fields, there have been a lot of studies and research done in this area. For instance, a research about the accuracy of ultrasonography was done with appendicitis (Pinto, 6). If all compares the controversial side of ultrasound with the actual outcome. This article finds that even though Ultrasound is less harmful and cheaper than imaging radiation like a CT-Scan it is also not as correct and sensitive and may predict wrong outcomes. Still, it is suggested that ultrasound is the best method for a first assessment of the patient and in case it is inconclusive, Computer Tomography should be used. Another study about the importance of ultrasound for the examination of acute abdomen suggests similarly that ultrasound being the more harmless option, should be used as a first imaging technique. It is specifically recommended in females and young patients, in order to limit their exposure to ionizing radiation. However, the article mentions as well as the previous one that in order to get a conclusive picture of the state of the patient, Computer Tomography is the better option. (Mazzei, M.A., et al.)

## Medical Devices (i.e., equipment) Transducer:

The transducer is the main part of the ultrasound machine. It produces the sound waves and receives its echoes. On its surface it has many piezoelectric crystals, which create an ultrasound wave through the so called piezoelectric effect. Energy in the form of electrical energy is applied to the crystals and they convert it into sound waves. This sound vibration induces a mechanical wave. All waves together make up the ultrasound beam. After the ultrasound waves get reflected by the tissue they reach the transducer again, which converts the mechanical energy of the acoustic waves into electric current. There are many different types of transducer probes for different examinations. The kind of use depends on the shape of the probe, while the resolution of the image as well as the depth of penetration are determined by the frequency of emitted soundwaves. Some probes may also be specially designed to be inserted through openings of the body, e.g. for ultrasound examinations of the intestinal tract.

### CU (central processing unit)

The Computer sends the electric current to the transducer and processes the data of the reflected sound echoes, which it receives in form of electric impulses from the transducer. The amount of the reflected energy determines the amplitude of the signal and relies on the different acoustic impedances of tissue structures. The time between the emission of a sound wave and the reception of the reflected signal gives information about the distance between the structures. By calculating the values the computer is able to produce an image on the monitor.

### Transducer pulse control:

Regulates the Amplitude, Frequency and duration of the ultrasound pulses emitted by the transducer.

### Coupling gel:

As there is a big difference in acoustic impedance between the air and the tissue a coupling gel is used to remove the air between transducer surface and the skin of the patient. This is to make sure that the ultrasound beam reaches the tissue.

The diagram illustrates the components and signal flow of an ultrasound machine. It includes a 'Sound sensor' (transducer) which sends 'Sound waves' to the 'Computer'. The 'Computer' sends 'Electrical signals' back to the 'Sound sensor'. The 'Sound sensor' also receives 'Vibration or sound' from the 'Patient' and sends 'Electrical signals' to the 'Computer'. The 'Computer' sends 'Electrical signals' to the 'Monitor', which displays the 'Image'. The 'Monitor' also receives 'Sound waves' from the 'Sound sensor'.

## Safety issues

Since ultrasonography does not use ionizing radiation (e.g. used during X-Ray) but soundwaves, there are only limited risks to the ultrasound procedure. It is generally possible to say that examination by ultrasound is safe. However, as ultra-sound waves can heat tissue slightly in some cases "potential side effects of gas in body fluids or tissues" ("Ultrasound imaging", 2019). Due to this, it is recommended to not use ultrasound for long times or regularly, e.g. with non-medical purposes and especially with fetal examination. There is still not enough research to give a clear conclusion on the safety of ultrasound.

## Conclusion

What future developments are envisaged in the area and what are the possible impacts on medicine?

As Ultrasonography is the least harmful compared to other examination methods, it should be a first examination method, however there still has to be research done, in order to give conclusive results. The aim should be to perfect the ultrasound technique, so e.g. CT does not need to be used for a clearer result.

## References

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The document explains the importance of ultrasound in clinical medicine, moreover how the ultrasound imaging works and some information about safety issues. The photo shows an ultrasound device and was taken in the department of biophysics of second faculty of medicine in prague.

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