

NONINVASIVE MEDICAL DIAGNOSTICS & TREATMENT USING ULTRASONICS

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INTRODUCTION

Noninvasive medical diagnostics and treatment tools are significantly increasing the pool of effective choices that are available to doctors and surgeons. Every part of the human body has already been explored with such tools and the reported success is very encouraging. With limited capability, visual and acoustic methods have been in use as diagnostic and NDT tools for hundreds of years. The introduction of such methods as radiography, MRI, magnetic field treatment and ultrasonics as well as computers and imaging devices made an innumerous impact on both fields. Ultrasound offers a wide range of possibilities and capabilities since the wave can be used in a broad frequency range, having variety of modes and can be operated in low and high power levels. Some of the most widely known applications are fetus imaging and kidney stones destruction. Medical ultrasonics offers safe, accurate and cost-effective tools, where no known health hazard is associated with its use at low power.

Ultrasonography has emerged as a medical diagnostics tool in the late 1960's and obstetrics has been one of the first applications. The most widely used techniques are pulse echo (3.5 to 7.0 MHz) and Doppler imaging (2 to 4 MHz). An example of a fetus imaging obtained in 1967 [1] is shown in Figure 1, where on the left a doctor is shown examining a pregnant woman and the right the B-scan scan image of the fetus. Currently used equipment offer real-time imaging, where the moving fetus is viewed on a color monitor. Pulse echo techniques are employed with the transducer coupled either in contact, immersion or using a liquid delay line. To obtain instant images, transducer array is used and the reflected signals are being monitored. The sensitivity and resolution have been improved to a level that allows viewing even the movements of fetal heartbeat and to conduct accurate measurements on the monitor. Such measurements form the cornerstone in the assessment of gestational age, size and growth in the fetus. Ultrasonics has progressively become an indispensable tool for many medical diagnostic applications and it is already playing a key role in the care of every pregnant woman.
Parallel to the industry use of Internet to disseminate information about the use of ultrasonics, the medical community is also forming homepages for this purpose (e.g. URL address http://www.rahul.net/intec/csites.html). To address ultrasonic medical issues, there is a society that is solely dedicated to this issue and it is known as the American Institute of Ultrasound in Medicine (AIUM). AIUM is an organization that is dedicated to advancing ultrasound in medicine and research through its educational, scientific, literary and professional activities.

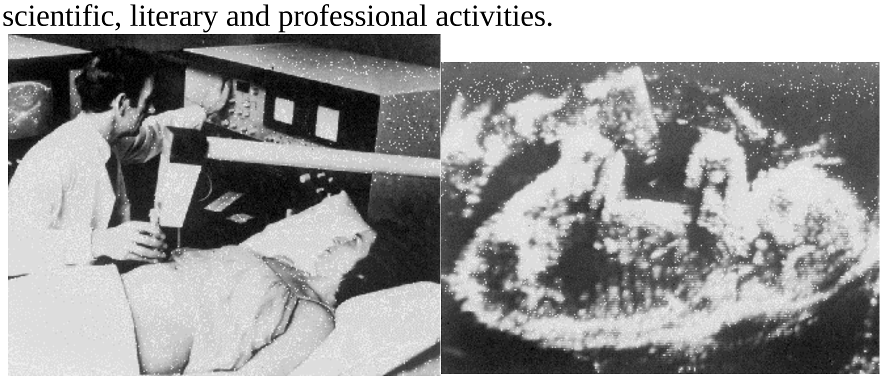

FIGURE 1: A pregnant woman being B-scanned and a view of the fetus.

MEDICAL DIAGNOSTIC APPLICATIONS

Pulse-Echo and Doppler imaging are the most widely used medical diagnostic methods.
Doppler - The Doppler shift principle has been used for a long time in fetal heart rate detectors. Recent development allows imaging and measurements of blood flow in the fetal blood vessels making the method a very effective diagnostic tool. The use of real-time color flow mapping clearly depicts the flow of blood in the vessels. Color Doppler is particularly indispensable in the diagnosis and assessment of congenital heart abnormalities and visualization of slow flow in small vessels. An example of the view of the heart, cross-section view of artery (2 cursors are used to gage its diameter) and a side view of blood flow Doppler imaging is shown in Figure 2.

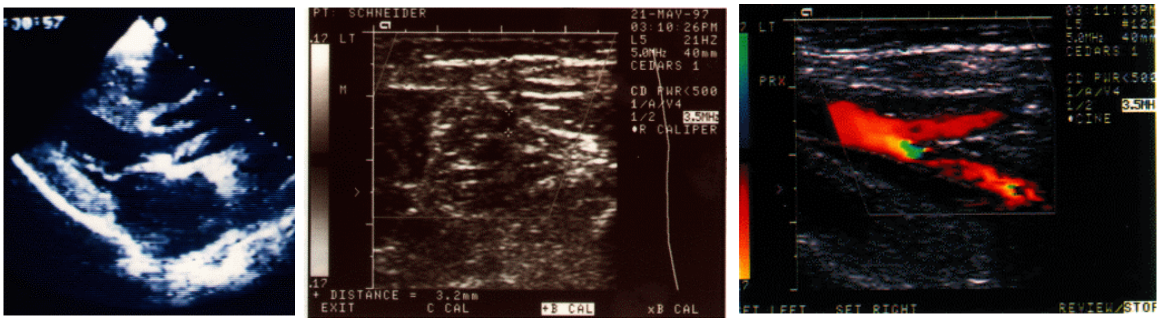

FIGURE 2: An image of the heart (left), cross section view of the artery (middle) and Doppler side-view of an artery (right).

Computerized Imaging - The development of real-time imaging with selectable combination of color hues onto shades of gray have added a powerful imaging capability for viewing subtle tissue details (e.g. left side of Figure 2). This enhancement provides a better interpretation of the ultrasonic images. The emergence of 3-D imaging for volumetric measurements further eased the image interpretation and its presentation to patients. Small abnormalities and cancerous areas can now be detected at a very early stage and significantly increasing the chances of patient full recovery.

Examples of standard medical applications of ultrasound include prostate, bladder, abdominal, obstetrics, gynecology, breast, thyroid, urology, and kidney. Pulse echo images are formed using transducers in the range of 3.5 to 7.5 MHz and the images are presented on a computer monitor with a scaled cursor for making measurements at various planes. Enlarged prostates and volume calculations are easily performed, bladder disorders can be clearly visualized and residual bladder volumes can be calculated very quickly. High-resolution breast images are obtained with pulse echo transducers and a fluid delay line. Such transducers permit visualization of structures immediately under the skin line and to position the transducer focal zone at the optimum depth for breast anatomy and pathology. Enhanced computer programs are making the procedure simple to perform with the results automatically displayed on the screen.

MEDICAL TREATMENT

Parallel to the use of low power for medical diagnostics, the application of high power ultrasonics as a medical treatment tool has grown rapidly. It was first introduced as a lithotripsy tool for kidney stones break up. Shock waves are created in pulses, which are causing stones to implode (rather than explode) and thus minimizing the collateral damage to adjacent tissues. This type of application has become a practical method in the late 1970s [2] and it is now a standard medical treatment procedure. In 1995, the authors started exploring the use of high power ultrasound as a means of destroying blood clots (see Figure 3)[3]. High power ultrasound induces shock-waves as a result of forming cavitation bubbles that implosively collapse [4, 5]. The cavitations are formed when the pressure associated with the wave (at the rarefaction phase) drops below the vapor pressure of the liquid in which the wave propagates. The implosion, i.e. collapse inward, of cavitation occurs mostly when the wave cycle turns to the compressive phase and it induces shock waves. The larger the cavitation bubble, the more violent its collapse, and the more effective its eroding effect [4]. However, the requirement for large wavelengths is subject to diffraction limits causing difficulties in focusing the wave. The authors have conceived a novel concept that allows modulation of LF and HF forming large and effective cavitation in a constrained focal zone. To aid in their research, the authors used flash-photography dark-field system to view the cavitation (see Figure 4).

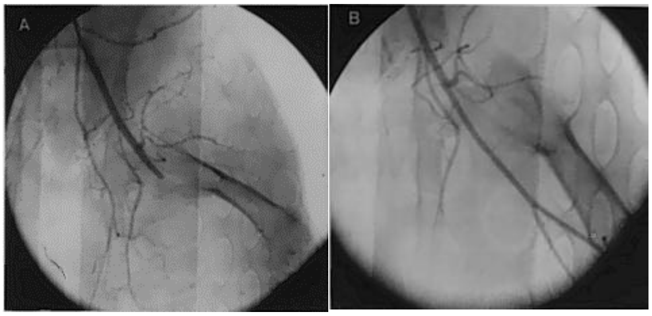

FIGURE 3: Angiographic example of the effect of transcutaneous ultrasound on the left iliofemoral artery of a rabbit, where:
A. Blocked artery.
B. Recovered artery after 30 minutes of treatment.

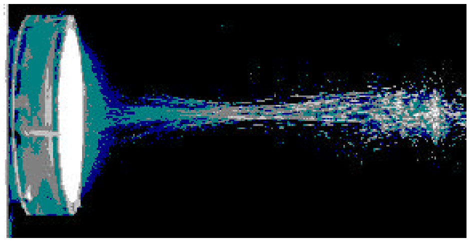

FIGURE 4: A flash photography dark-field view of cavitations in water induced by a high power ultrasonic transducer is shown.

TRANSITION OF ULTRASONICS BETWEEN NDE AND MEDICAL
CAT scan and MRI are examples of NDE methods that found medical diagnostic practical applications prior to NDE of structures in the industry. The availability of greater resources and the capability of these methods to provide clear and detailed images, which are unmatched by other techniques, led to their medical application. Ultrasonics found parallel development path in both fields. While the two communities are using similar tools, limited cooperation between the two has been reported. Cooperation between the two communities can have an important impact on applications to diagnostics and NDE and members of ASNT and the AIUM are encouraged to explore such teaming.

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