

Biomedical ultrasound: Illuminating the inner world of medicine

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AUTHORS' CONTRIBUTION: (A) Study Design · (B) Data Collection · (C) Statistical Analysis · (D) Data Interpretation · (E) Manuscript Preparation · (F) Literature Search · (G) No Fund Collection

ABSTRACT

Biomedical ultrasound has emerged as a revolutionary and indispensable tool in modern healthcare. This article explores the principles, techniques, and applications of ultrasound in the medical field. Biomedical ultrasound utilizes high-frequency sound waves to generate real-time images of internal structures and tissues by analysing reflected waves. Various ultrasound imaging techniques, including 2D, 3D, and Doppler ultrasound, finds applications in obstetrics, radiology, cardiology, emergency medicine, oncology, and rehabilitation. The advantages of biomedical ultrasound lie in its non-invasiveness, real-time imaging, and absence of ionizing radiation, making it safe and patient-friendly. However, its limitations arise from its inability to penetrate dense bone or air-filled structures. As research and technology continue to evolve, biomedical ultrasound promises to play an increasingly pivotal role in enhancing diagnostic and therapeutic practices, illuminating the path towards better healthcare outcomes.

Keywords: Biomedical ultrasound; Ultrasound imaging; Medical ultrasound; High-frequency sound waves

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Word count: 1590 **Tables:** 00 **Figures:** 00 **References:** 10

Received: 03.07.2023, Manuscript No. IPIBS-23-13958; **Editor assigned:** 05.07.2023, PreQC No. P-13958; **Reviewed:** 19.07.2023, QC No. Q-13958; **Revised:** 24.07.2023, Manuscript No. R-13958; **Published:** 28.07.2023

INTRODUCTION

In the ever-evolving landscape of modern medicine, technological advancements have continuously pushed the boundaries of diagnostic and therapeutic practices, revolutionizing patient care. Among these breakthroughs, biomedical ultrasound has emerged as a remarkable tool that has transformed the way healthcare professionals perceive and interact with the human body [1]. Utilizing high-frequency sound waves, biomedical ultrasound offers a non-invasive and real-time window into the inner workings of the human anatomy, opening up new possibilities for accurate diagnosis, targeted treatment, and improved patient outcomes.

Biomedical ultrasound, often referred to as medical ultrasound, harnesses the principles of sound wave physics to create detailed images of internal structures and tissues. These high-frequency sound waves, beyond the range of human hearing, are emitted by a transducer and then directed into the body. As the sound waves traverse through different tissues with varying acoustic properties, such as density and elasticity, they encounter tissue interfaces, resulting in the reflection, refraction, and absorption of the waves. By analysing the reflected waves, sophisticated ultrasound machines construct intricate images in real-time, providing clinicians with invaluable insights into the hidden intricacies of the human body [2].

The versatility of biomedical ultrasound lies in its ability to employ various imaging techniques tailored to specific medical applications. The conventional 2D (Two-Dimensional) ultrasound produces cross-sectional images of organs and tissues, making it a cornerstone in obstetrics, radiology, and abdominal imaging. Its three-dimensional counterpart, 3D ultrasound, takes imaging step further, reconstructing volumetric images by combining multiple 2D scans. This advancement has proven particularly beneficial in obstetric care, allowing expectant parents and healthcare providers to visualize the developing foetus in greater detail, enhancing prenatal diagnostics and patient engagement [3].

In the pursuit of real-time information and dynamic assessments, the 4D (Four-Dimensional) ultrasound brings the element of time into the equation. By capturing moving structures, such as a beating heart or a developing fetus in utero, 4D ultrasound enhances the evaluation of cardiac function, fetal behavior, and development. Furthermore, the specialized Doppler ultrasound technique focuses on assessing blood flow through vessels, enabling the detection of abnormalities and disorders related to circulation, making it an essential tool in cardiology and vascular medicine.

The applications of biomedical ultrasound span across multiple medical disciplines, proving its indispensability in diverse clinical settings. In obstetrics, it facilitates prenatal care and allows obstetricians to monitor fetal growth, assess placental health, and identify potential anomalies. In radiology, it aids in the evaluation of abdominal organs like the liver, gallbladder, and kidneys, guiding clinicians in diagnosing diseases and planning interventional procedures. Cardiologists heavily rely on echocardiography, a form of ultrasound, to evaluate heart structure and function, assess valve disorders, and diagnose various cardiovascular conditions.

Moreover, the versatility of biomedical ultrasound extends its reach to emergency medicine, where it plays a crucial role in rapidly assessing trauma patients for internal injuries, aiding in swift and accurate diagnosis. In oncology, ultrasound aids in detecting tumors, characterizing tissue composition, and guiding needle biopsies, contributing to early diagnosis and treatment planning. Additionally, therapeutic ultrasound finds application in physical therapy and rehabilitation, employing sound waves to provide deep tissue heating, promote blood flow, and accelerate tissue repair for injuries and musculoskeletal disorders [4].

While biomedical ultrasound boasts numerous advantages, including its non-invasive nature, real-time imaging capabilities, portability, and minimal risk to patients, it does have its limitations. Due to its reliance on sound waves, biomedical ultrasound encounters challenges when imaging structures obscured by dense bone or air-filled organs, limiting its applicability in certain scenarios.

As research and technology continue to advance, biomedical ultrasound remains at the forefront of medical innovation, promising exciting possibilities for the future of healthcare. On-going developments in transducer design, image processing algorithms, and artificial intelligence integration hold the potential to further enhance the accuracy, resolution, and accessibility of ultrasound imaging, empowering clinicians with even greater diagnostic precision and therapeutic capabilities [5-6].

In this article, we delve deeper into the principles, techniques, applications, and the impact of biomedical ultrasound in modern medicine. By shedding light on its diverse applications and exploring the on going advancements in this field, we aim to showcase the vital role biomedical ultrasound plays in illuminating the inner world of medicine, ultimately contributing to improved patient care and a healthier future for all.

DISCUSSION

In the vast and ever-evolving field of medicine, technological advancements have consistently played a pivotal role in revolutionizing diagnostic and therapeutic practices. Among these innovations, biomedical ultrasound has emerged as a powerful and non-invasive tool with a wide range of applications. This article explores the fascinating world of biomedical ultrasound, its principles, uses, and its crucial role in modern healthcare.

Understanding biomedical ultrasound

Ultrasound, in general, refers to sound waves with frequencies above the range of human hearing. Biomedical ultrasound, in particular, involves the use of these high-frequency sound waves for medical purposes. Typically, the frequencies used in medical ultrasound range from 2 to 20 megahertz (MHz).

Ultrasound imaging relies on the principle of sound wave reflection, refraction, and absorption as they pass through different tissues of the body. When the ultrasound waves encounter tissue interfaces with varying acoustic properties, such as density and elasticity, some of the waves bounce back to the transducer (the device emitting the ultrasound waves). By analysing these reflected waves, a detailed image of the internal structures can be generated in real-time [7].

ULTRASOUND IMAGING TECHNIQUES

There are several ultrasound imaging techniques commonly used in the medical field:

2D (Two-Dimensional) ultrasound

This is the most common form of ultrasound imaging, producing cross-sectional images of organs, tissues, and blood vessels. It is widely used in obstetrics, cardiology, and general abdominal imaging.

3D (Three-Dimensional) ultrasound

By combining multiple 2D images from different angles, 3D ultrasound creates a more comprehensive and detailed representation of internal structures. This technique is valuable in obstetrics for visualizing the fetus and aiding in prenatal diagnostics.

4D (Four-Dimensional) ultrasound

This is an extension of 3D ultrasound, with the added dimension of time. It allows for real-time visualization of moving structures, such as a fetus in the womb, providing valuable insights into foetal development and behavior [8].

Doppler ultrasound

This specialized technique is used to assess blood flow through vessels. By measuring the frequency shift of reflected sound waves from moving blood cells, Doppler ultrasound can detect abnormalities in blood flow and identify conditions such as deep vein thrombosis or cardiovascular disorders.

Applications of biomedical ultrasound

Biomedical ultrasound finds applications in various medical disciplines, making it an indispensable tool for healthcare professionals:

Obstetrics

One of the most well-known uses of ultrasound is in monitoring and assessing fetal development during pregnancy. It allows obstetricians to visualize the fetus, measure growth, and detect potential anomalies.

Radiology

Ultrasound imaging is extensively used to examine abdominal organs, such as the liver, gallbladder, kidneys, and pancreas, aiding in the diagnosis of diseases and guiding interventional procedures.

Echocardiography cardiology

A form of ultrasound is critical in evaluating heart structure and function, assessing valve disorders, and diagnosing heart conditions.

Emergency medicine

Ultrasound is often used in emergency settings for rapid assessment of trauma patients, assisting in identifying internal injuries or guiding the insertion of central lines.

Oncology

Biomedical ultrasound can help in detecting tumors, characterizing tissue composition, and guiding needle biopsies, enabling early diagnosis and treatment planning.

Physical therapy and rehabilitation

Therapeutic ultrasound is used for deep tissue heating, promoting blood flow, and accelerating tissue repair in cases of injuries and musculoskeletal disorders.

Advantages and limitations

Biomedical ultrasound offers numerous advantages,

including non-invasiveness, real-time imaging, portability, and absence of ionizing radiation. It is generally safe, with minimal risks or side effects. However, its effectiveness may be limited in cases where the ultrasound waves cannot penetrate dense bone or air-filled structures, reducing its utility in certain situations.

CONCLUSION

Biomedical ultrasound has transformed the landscape of modern medicine, providing healthcare professionals with valuable insights into the inner workings of the human body without resorting to invasive procedures. Its applications are vast and continually expanding, and ongoing research and technological advancements hold the promise of further enhancing its diagnostic and therapeutic potential. As a non-invasive and patient-friendly imaging modality, biomedical ultrasound continues to be a beacon of light illuminating the path towards better healthcare outcomes [9,10].

ACKNOWLEDGEMENT

None

CONFLICT OF INTEREST

None

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