RECENT ADVANCES IN OPHTHALMIC ULTRASONOGRAPHY

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Abstract By

Dr. Mohammed Adel Abdel Rhman Mosleh

Ultrasound is an acoustic wave with a frequency above the audible range of 20 **KHz.** The principle of ultrasonic investigation in ophthalmology is to deliver a series of ultrasonic pulses to the eye by a `transducer probe' which are reflected like an echo by any solid or semisolid surface within the eye and are received by the same probe, rectified, amplified and indicated on screen.

One of the most significant advances in ophthalmic ultrasound is the development of ultrasound biomicroscopy (**UBM**). In 1990 **Pavlin** and colleagues described the first high frequency ultrasound (**50-100 MHz**) in ophthalmology. At this frequency, microscopic images of tissues are obtained at a magnification approaching that of light microscopy. However, high resolution is won against the loss of penetration. It has many applications in diagnosis of various types of glaucoma, intraocular tumors, inflammations, trauma and corneal diseases.

Recently, the **VHF ultrasound (Artemis)** was developed to provide a very high resolution ultrasound B-scan imaging of the anterior segment including high-precision 3-D mapping of individual corneal layers, and axial length .The Artemis is designed to scan in an arc of adjustable radius, thus following the curved surfaces. Also, it uses a digital processing technology and reverse immersion technique. It is widely used in preoperative and postoperative preparation of LASIK patients and many other applications.

Development of **duplex scanners and color Doppler** instruments in the 1980s has facilitated their use in ophthalmology. Power Doppler (PD) has three times the sensitivity of conventional Color Doppler in detecting blood flow and it is very useful in imaging of vascular lesions of the globe and orbit.

Three-dimensional (3D) ultrasound is a promising technology. The 3-D image is constructed from a series of ordered B-scan planes that are processed by special software. It has many advantages and clinical applications such as outlining the intraocular masses and calculating their volumes.

Other promising new developments in the field of diagnostic ultrasound include Tissue characterization and Echo contrast agents**.** **Tissue characterization** technology analyzes the echo (reflected amplitude in relation to used frequency) and calculates the scatter size and concentration of a given tissue, presenting them by false colors (each color assigned to special scatter size ad concentration) in the original b-scan, just like histological sections. **Echo contrast agents** (such as gas microbubbles) act by increasing the backscatter effect of ultrasound in vascular regions. They can be used with "harmonic imaging" to image the contrast agent maximally while inhibiting surrounding artifacts. Therefore, it is very useful in imaging small vessels and vascular lesions.

Other developments in ultrasound in general include refinement in transducer's material and technology, leading to improvements in sensitivity and bandwidth. **20-MHz transducer** and **annular array** are examples of this development.

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Mohammed Adel Abdel Rhman Mosleh

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Introduction

Ultrasound is an acoustic wave with a frequency above the audible range of 20 **KHz.** Echoes are produced when ultrasound waves encounter an interface in which two different materials have different acoustic impedances[(1)] . The principle of ultrasonic investigation in ophthalmology is to deliver a series of ultrasonic pulses to the eye by a `transducer probe' which are reflected like an echo by any solid or semisolid surface within the eye and are received by the same probe, rectified, amplified and indicated on an oscilloscope [(2)].

The early pioneers of ophthalmic ultrasound include **Mundt** and **Hughes**, **Oksala** and **Lehtinen**, and **Gernet**, and they were concerned with the introduction of time-amplitude **A-scan**. **Baum** and **Greenwood** jointly reported the first application of **"brightness modulated**" **B-scan** in ophthalmology and they employed an immersion method. In 1972 **Bronson** and **Turner** described the first **contact B-scan**, making ultrasound an easy and patient friendly imaging modality [(3)].

Development of duplex scanners and colour Doppler instruments in the 1980s has facilitated their use in ophthalmology. Recently, it is well known that Power Doppler (PD) has three times the sensitivity of conventional Color Doppler in detecting blood flow and it is very useful in imaging of vascular lesions of the globe and orbit [(3)].

One of the most significant advances in ophthalmic ultrasound is the development of ultrasound biomicroscopy (**UBM**). In 1990 **Pavlin** and colleagues described the first high frequency ultrasound (**50-100 MHz**) in ophthalmology and in 1991 published its clinical application in imaging of the anterior eye segment. The term ultrasound biomicroscopy (UBM) as coined by Pavlin is indicative of the highly magnified; Clear, near microscopic, in vivo images of the anterior segment in such a way not previously possible on conventional B-scan [(3)]**.** Recently, **Silverman** and colleagues developed a high-frequency **annular array transducer** with higher depth of field [(4)].

During the last decade newer technologies have been in a gestational stage of development and may soon become more widely available [5]. **Three-dimensional** (3D) ultrasound is a good example. The 3-D image is constructed from a series of ordered B-scan planes that are processed by special software[6].

Other promising new developments in the field of diagnostic ultrasound include **tissue characterization** and **Echo contrast agents.** The science of ultrasonic tissue characterization (UTC) is the untangling of hidden patterns in pulse-echo data to extract more information about tissue function and pathology than that seen in conventional images[7]. **Echo contrast agents** (such as gas microbubbles) act by increasing the backscatter effect of ultrasound in vascular regions. They can be used with "harmonic imaging" to image the contrast agent maximally while inhibiting surrounding artifacts. Therefore, it very useful in imaging small vessels and vascular lesions [3].

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Aim of the work:

The aim of this study is to describe the new technologies of ultrasonic imaging of the eye (such as very high frequency ultrasound, 3D US, tissue characterization, harmonic imaging of contrast agents and Doppler scanner) and its impact on improved diagnosis and monitoring of ocular diseases.

References

1-Hyden B. , Kelly L. , Singh A. Ultrasound Clinic 2008; 3 : 179.
2- Buschmann W.H. Diagnostic Ultrasonography in Ophthalmology. Indian J Ophthalmology 1966; 14: 105-116.
3- ATTA H. R. Br J Ophthalmol. 1999; 83: 1246-1249 .
4- Wolffsohn J. , Davies L. Advances in Ocular Imaging, Expert Rev Ophthalmol. 2007; 2(5):755-767.

5- Coleman D. , Silverman R. , Daly S. et al; Advances in Ophthalmic Ultrasound. Radiologic Clinics of North America 1998; 36: 1073-1082.

6- Coleman D. , Silverman R. , Daly S. et al; Three-dimensional Ultrasound Imaging: Clinical Applications. Ophthalmology 1998; 105: 300-306.

7- John S. , Sujana H. , Suresh S. et al ; Ultrasonic Characterization of Malignant Melanoma of Choroid. Indian Journal of Ophthalmology 1998; 46: 153-157.

Introduction

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Other promising developments in ultrasound in general include refinement in transducer's material and technology, leading to improvements in sensitivity and bandwidth [3]**.**

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Physics of Ultrasound

Sound is mechanical energy that propagates longitudinally through elastic media as alternating zones of compression and rarefaction (Figure 1.1). It requires a medium of a molecular nature to propagate (can't propagate in vacuum). (8)

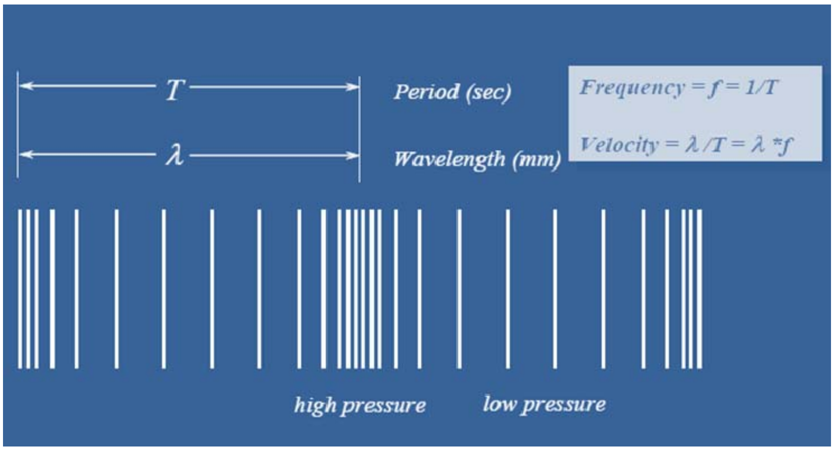

Figure (1.1) Sound wave propagation (9)

Ultrasound is simply sound waves, like audible sound. It differs from a sound wave in that its frequency is higher than **20,000** cycles per second or **20 kHz** (kilohertz). The audible range of human ear is from **20 Hz** to **20 kHz**. Because ultrasound is a wave, it transmits energy just like an electromagnetic wave or radiation .Unlike an electromagnetic wave, however, sound requires a medium to travel in and thus cannot propagate in a vacuum. (10)