Ultrasound biomicroscopy Applications in Glaucoma

An Essay

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Summary

Ultrasound biomicroscopy is a new imaging technique that uses high frequency ultrasound to produce images of the eye at near microscopic resolution.

Fifty mega hertz is an ideal compromise between depth and resolution to visualize the entire anterior segment.

There are three main components of the ultrasound biomicroscopy machine transducer, high-frequency signal processing and precise motion control.

In ultrasound biomicroscopy the probe may be used in the supine or the sitting position and the eye is open.

Ultrasound biomicroscopy systems are suitable for imaging of virtually all anterior segment anatomy and pathology, including the cornea, iridocorneal angle, anterior chamber, iris, ciliary body and lens.

Ultrasound biomicroscopy provides objective, high resolution, cross-sectional information on the anterior segment anatomy and is sometimes useful for understanding the mechanism of glaucoma.

Several types of glaucoma are caused by structural abnormalities of the anterior segment of the globe. This is particularly true of angle closure glaucoma and infantile glaucoma. The ability of ultrasound biomicroscopy to image the anterior chamber structures in depth at high resolution makes it a useful tool in glaucoma research and clinical practice.

Ultrasound biomicroscopy is useful in analyzing angle closure glaucoma and the mechanisms that produce it. Other ocular structures

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Contents

List of abbreviations

AC	Anterior chamber
ACD	Anterior chamber depth
ACG	Angle closure glaucoma
AOD	Angle opening distance
ARA	Angle recess area
AS-OCT	Anterior segment optical coherence tomography
C	The speed of sound
CB	Ciliary body
CD	Choroidal detachment
Cm	Centimeter
Co	Cornea
Cp	Ciliary process
CRS	Cogan-Reese syndrome
CS	Chandler's syndrome
dB	decibel
DS	Deep sclerectomy
DSCI	Deep sclerectomy with collagen implant
Er: YAG	Erdium yttrium aluminum garnet
Hz	Hertz
ICE	Iridocorneal endothelial syndrome
IOP	Intraocular Pressure
Ir	Iris
JPOAG	Juvenile primary open angle glaucoma
KHz	Kilo Hertz
LPI	Laser peripheral iridotomy
MHz	Mega Hertz
MRI	Magnetic resonance imaging
µ	Microns
mm	millimeters
Nd: YAG	Neodymium: YAG
NPT	Nonpenetrating trabeculectomy
OAG	Open angle glaucoma
OCT	Optical coherence tomography
PAC	Primary angle closure
PACG	Primary angle closure glaucoma
PACS	Primary angle closure suspect
PES	Pseudo-exfoliation syndrome

PI	Plateau iris
PIA	Progressive iris atrophy
PIC	Plateau iris configuration
PIS	Plateau Iris Syndrome
POAG	Primary open angle glaucoma
PPI	Pseudo plateau iris syndrome
PVDF	Polyvinylidene Difluoride
PVDF-TrFE	Polyvinylidene fluoride Trifluoroethylene
RHAI	Reticulated hyaluronic acid implant
RPB	Relative pupillary block
Sc	Sclera
SCF	Suprachoroidal fluid
S-WS	Sturge Weber syndrome
TCPD	Trabecular ciliary processes distance
TDM	Trabeculo- Descemet's membrane
TIA	Trabecular iris angle
TM	Trabecular meshwork
TMAL	Trabecular meshwork height – axial length ratio
TMIA	Trabecular meshwork iris angle
UBM	Ultrasound biomicroscopy
YAG	Yttrium Aluminum Garnet
ט	Frequency
ג	Wavelength
2D	Two dimensional
3D	Three dimensional

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Introduction

Ultrasound biomicroscopy [UBM] is an imaging technique that uses high frequency ultrasound to produce images of the eye at near microscopic resolution [1].

UBM was applied in 1988. It was originally designed to have a field of view of 2 millimeters [mm] × 2 mm and a frequency of 100 Mega Hertz [MHz]. With it the first views of enucleated eyes [unsuitable for corneal transplantation] were obtained. The results revealed fascinating details of the angle of the eye, the cornea, the sclera, the iris and the ciliary body. The visualization of Schlemm's canal at these frequencies was quite variable. Imaging provided outstanding resolution but didn't permit appreciation of larger deeper structures [2].

Accordingly, the next design incorporated transducers ranging from 50- 80 MHz with a field of view of 4 mm × 4 mm. This proved to be a useful compromise that allowed all of the important structures of the anterior globe to be well visualized [3].

The first clinical images were made in 1990 using a water bath approach. Scanning was performed by placing the probe close to the area of interest and observing the resulting image on the screen. Fine movement of the probe was performed manually with reference to the screen image. The probe and preamplifier were supported by a mechanical arm assembly to help reduce motion artifacts [4].

UBM has been proved to be a valuable investigative tool that provides a foundation for future studies of specific glaucoma types such as open angle glaucoma [OAG] and angle closure glaucoma [ACG] which may be caused by pupillary block, plateau iris syndrome, lens induced angle closure, iris cysts and tumors, ciliary body rotation due to effusion, dark room provocative testing or malignant glaucoma [5, 6].

UBM helps to study the angle in great detail. The exact configuration of the iris, ciliary body and its processes can be defined. These structures can be seen in the presence of an opaque media. The angle can be quantified and the values can be followed up after treatment [7].

The UBM is the only way to fully assess the extent of the iris concavity in pigment dispersion syndrome and pigmentary glaucoma [8].

Unlike gonioscopy and micro endoscopy, UBM provide valuable intra-operative information about the tissue depth that the surgeon's instruments have reached and about the tissue density beyond the trabecular meshwork [TM] [9].

Precise localization of the site of blockage of failing filtering blebs facilitates slit lamp trans-conjunctival needle revision and restoration of flow in many eyes [10].

Aim of work

The aim of this work is to illustrate the value of UBM in diagnosis, management and follow up of glaucoma.

Chapter [1]

THE PHYSICS OF ULTRASOUND

Dr. Charles Pavlin & Prof. Stuart Foster developed the first practical UBM in the early 1990s. They developed three probes 50, 80 & 100 MHz for clinical trials [2- 13]. The probes of 80 & 100 MHz were used to see the cornea and the anterior chamber as the depth of penetration is only 2 mm. They reached to a conclusion that a 50 MHz is an ideal compromise between depth and resolution to visualize the entire anterior segment [14].

Coleman, Silverman and their group at Cornell Medical College (New York, NY, USA) independently developed a UBM system emphasizing the processing of raw radiofrequency echo data acquired in sequential planes suitable for 3D analysis, especially corneal biometric analysis [15]. This system was also uniquely incorporated an optical sub-system for fixation, centration and display of eye position [16].

Basic physics of high frequency ultrasound imaging

Sound occupies the range from 10 Hertz [Hz] to 20 Kilo Hertz [KHz] of acoustic spectrum. The ultrasonic frequency occupies from 20-100 KHz. In body imaging, where significant penetration of the tissues is needed, frequencies between 3.5-5 MHz are incorporated [4]. These frequencies have the ability to penetrate the tissues to a depth of 15-20 centimeter [cm] and still return signals of sufficient strength to form an image. As the frequency increases, the ultrasound is more strongly attenuated, reducing penetration [15].

Higher frequencies (7-10MHz) can be used in imaging small parts such as visualization of the eye, where penetration of 4-5cm is sufficient [4].

The development of transducers for very high frequency ultrasound imaging was based on the polymer polyvinylidene difluoride (PVDF). These transducers were sensitive over a very broad range of frequencies [15].