Ophthalmic Ultrasound

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Disclosures

- No financial interest in any of the products or companies discussed

Sound Waves & Their Properties

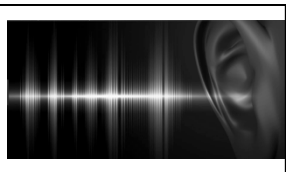
Properties of Sound Waves

- Wavelength
- Frequency
- Velocity
- Reflectivity
- Angle of Incidence
- Absorption

Sound Waves passing through an object are slowed by...

- *Permeability* - how readily the object allows the sound wave to pass through it
- *Permittivity* - the ability of a substance to store electrical energy in an electric field

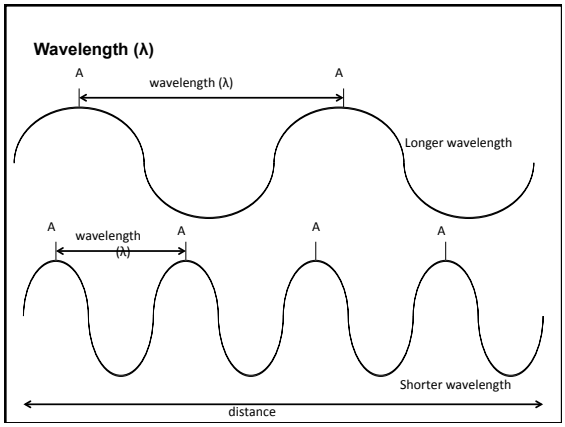
Sound Waves

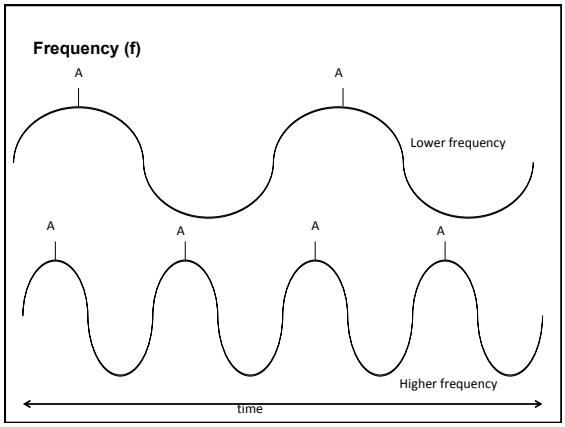


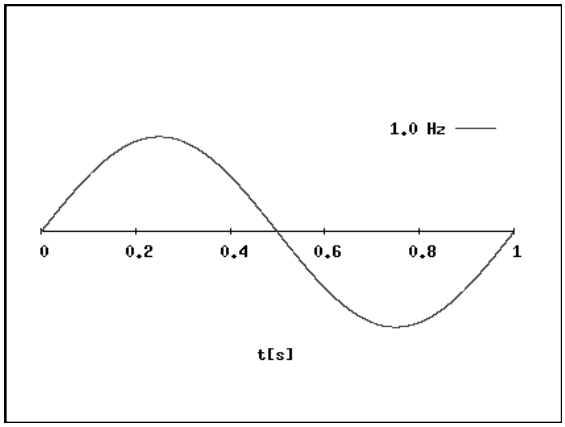
- Sound travels faster through solids or liquids?
  - Aqueous & Vitreous = 1,532 m/s
  - Cornea & Lens = 1,641 m/s

Sound Waves

- *Wavelength* is the <u>distance</u> from one peak of the wave's electric field (wave's peak/crest) to the next, & is inversely proportional to the *frequency* of the wave
- *Frequency* is the number of <u>oscillations (or cycles) per second</u>







Relationship: Wavelength & Frequency

$$\lambda = \frac{300}{f}$$

- λ = wavelength (in meters)
- f = frequency (in MegaHertz = MHz)

⇨(Higher freq. = higher resolution = shallower depth)

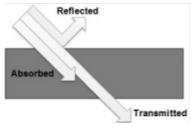
Relationship: Wavelength & Frequency

- Since eye short (23.5mm), standard B-Scans manufactured with short wavelength/high frequency (10 MHz) for high image resolution
- UBM at 20-50 MHz for ultra resolution (only penetrates *5-10mm*)

Velocity

- The rate at which a sound wave's position changes in a particular direction
- Sound wave velocity is dependent on the density of the medium through which its passing
- ⇨There are known sound wave velocities when passing through different ocular structures

Reflectivity

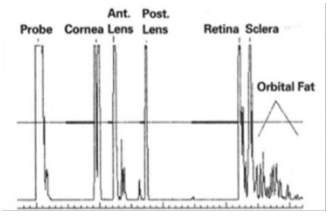


- When sound passes from one medium to another of a different density, part of the sound is reflected back to the probe (= *echo*), while rest passes through (i.e. is refracted)

⇨Greater the density difference, the stronger the echo (i.e. higher the reflectivity)

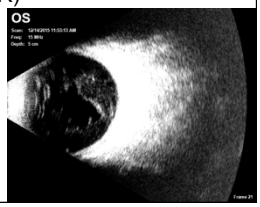
Reflectivity

- A-scan:
  - Thin, parallel sound beam emitted by probe; echos represented as **spikes** from baseline (stronger echo=higher spike)



Reflectivity

- B-scan:
  - Oscillating sound beam emitted by probe to image a slice of tissue; echos represented by **dots** on a screen (stronger echo = brighter dot)
  - Pulse-Echo (think SONAR)



Angle of Incidence

- Critical for ultrasonography
- If probe not held perpendicular to the area of interest, some of the echo is reflected away from the probe tip & lost

⇨ (i.e. oblique angle = compromised ultrasound)

⇨A-Scan: greater the perpendicularity, *steeper* & *higher* the spike from baseline

⇨B-Scan: greater the perpendicularity, *brighter* the dots

Absorption

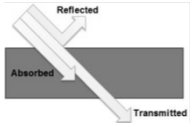


Image from: study.com

- Ultrasound is absorbed by *every* medium through which it travels
- More dense the medium, the greater the absorption (thus more sound wave loss for ensuing structures)

⇨Trans-*conjunctival* applanation yields higher resolution scan than trans-dermal (since doesn't have to traverse tarsal plate/lid)

For sound to be "ultrasonic," frequency must be >20,000 oscillations per second (i.e. >20 KHz, which is inaudible to the human ear)

A United States Navy F/A-18F Super Hornet in transonic flight

Ophthalmic Ultrasound: How Does it Work?

- Applanated probe emits series of pulsed high frequency (ultrasonic) sound waves into eye
- As ultrasonic waves strike various intraocular tissues/ structures, some are reflected back to probe, which routinely pauses for microseconds to receive signals & reconstruct on-screen (i.e. pulse-echo system) = think sonar!
- Probe then converts reflected sound waves to electrical signal, either as line (A-scan) or dots on screen (B-scan)

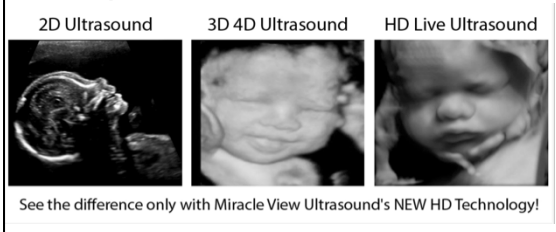
Ophthalmic ultrasound cannot be used to:

- A) Visualize intraocular structures not otherwise directly visible on examination
- B) Differentiate iris vs. ciliary body lesions
- C) Measure axial length to determine IOL power
- D) Differentiate intraocular tumors
- E) Differentiate optic nerve drusen from papilledema
- F) Measure corneal thickness
- G) Treat glaucoma
- H) None of the above (i.e. all are true)

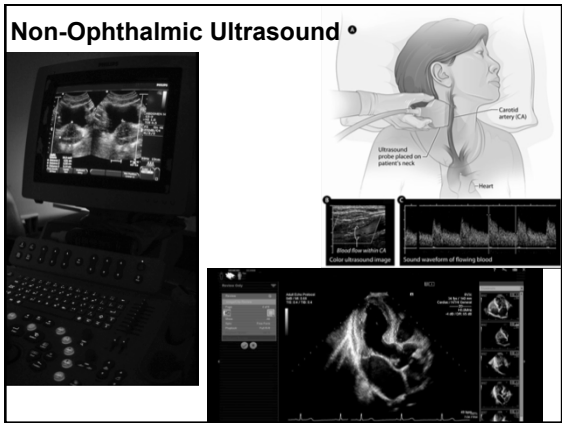
Ophthalmic Ultrasound (a.k.a. Echography)

- Uses ultrasonic sound waves to:
  - Determine axial length of the eye (IOL calculations) **= A-scan**
  - Examine the eye when direct visualization is impeded/compromised **= B-scan**
  - Dx & diff. b/t conditions = **B-Scan, A-Scan, UBM**
  - In OCT = **A-scans & B-scans**
  - Measure central corneal thickness = **Pachymetry**
  - To treat ocular disease?

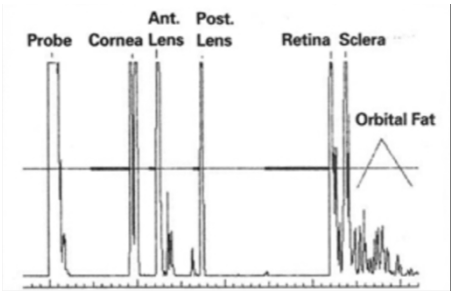
Non-Ophthalmic Ultrasound



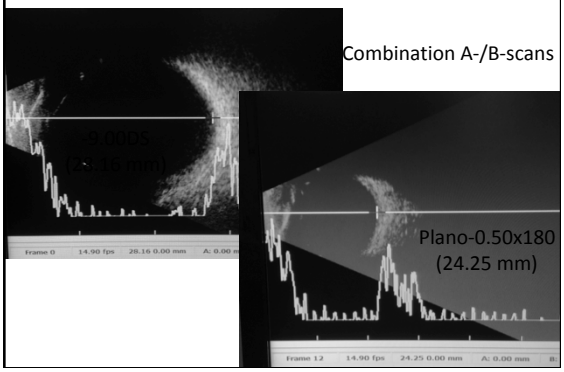
Non-Ophthalmic Ultrasound



Components of an A-Scan



Axial Length Measurements (a.k.a Biometry)



Types of Ophthalmic A-Scans

- 1) Applanation

Types of Ophthalmic A-Scans

2) Immersion

Types of Ophthalmic A-Scans (cont.)

- 3) IOL Master (Zeiss)

Types of Ophthalmic B-Scans

- Standard

- Ultrasound Biomicroscopy (UBM)...

UBM

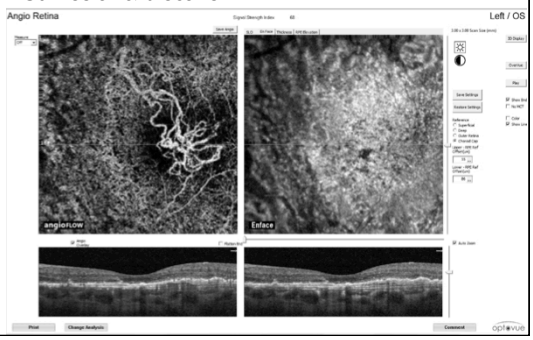
- Higher frequency
- Better resolution
- Less penetration into globe

Pachymetry

- Measurement of corneal thickness
  - Optical; or
  - Using ultrasound technology

Optical Coherence Tomography (OCT)

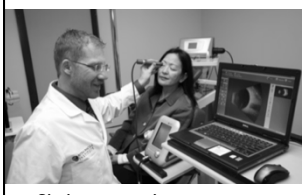
- Utilizes a- & b-scans



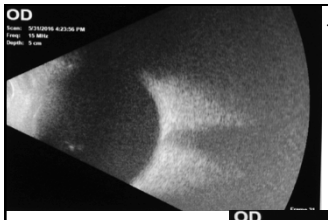
B-Scan Adjustments

- Gain = the "sensitivity" of the instrument
  - Increase gain = weaker signals more easily viewed
  - Decrease gain = weaker signals disappear
- Contrast
- Intensity

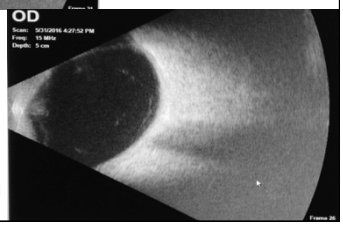
Ophthalmic Ultrasound Technique



- Sitting or supine
- Trans-palpebral or Trans-conjunctival (anesthetic)
- With or without ultrasound gel (or artificial tear gel/ointment)

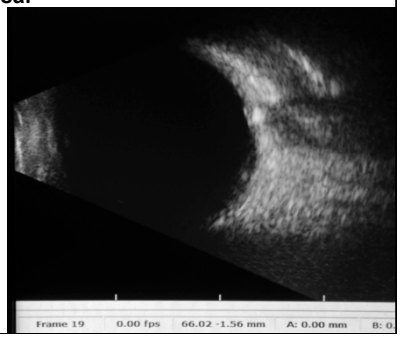


Trans-dermal

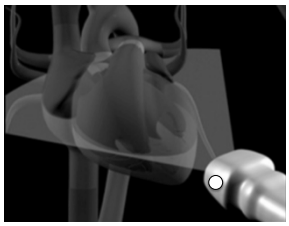


Trans-conjunctival

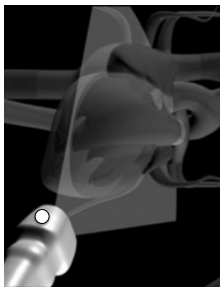
What's the orientation of this B-Scan?
A) Nasal-to-Temp
B) Temp-to-Nasal
C) Sup-to-Inf
D) Inf-to-Sup
E) Can't tell



Ophthalmic Ultrasound Technique

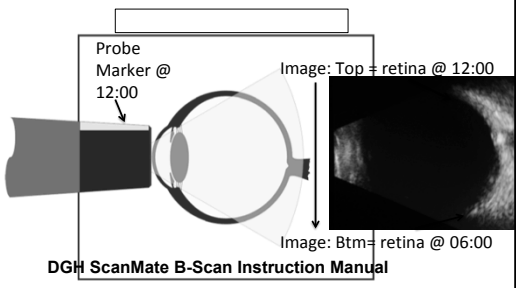


Probe Position = 9 o'clock



Probe Position = 12 o'clock

Axial Probe Positions – An axial scan provides an image of the posterior globe, with the optic nerve centered on the right side of the image. The probe is positioned so that it is centered on the cornea while the patient is looking forward. When properly aligned, the optic nerve will be centered on the right side of the image.

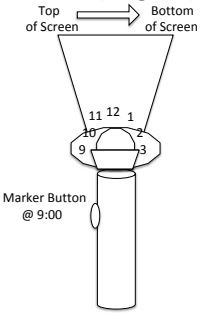


DGH ScanMate B-Scan Instruction Manual

Use the selection tool to indicate the meridian being scanned, where the yellow marker matches the orientation of the marker on the tip of the probe. Once the

B-Scan Probe Positioning:

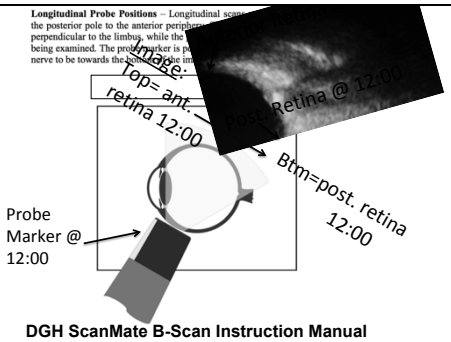
Axial (1° gaze)



Remember, the Probe Marker Position (in clock hour), does not necessarily match the clock hour(s) on the retina being scanned.

Also, on the B-scan image, to the left is closest to the face of the probe (in our case more anterior) and moving to the right on the image is moving further into the eye

Longitudinal Probe Positions – Longitudinal scans provide an image of the posterior pole to the anterior periphery perpendicular to the limbus, while the patient is looking toward the area of the eye being examined. The probe marker is pointed toward the optic nerve to be towards the [illegible]



DGH ScanMate B-Scan Instruction Manual

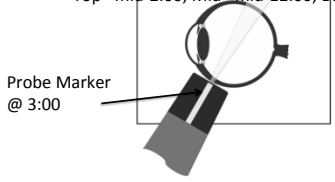
For a 12:00 Longitudinal scan, the marker on the tip of the probe is pointed toward the area being examined at 12:00. The probe is positioned at 6:00, which is opposite of the area being examined.

Use the selection tool to indicate the meridian being scanned. Once the desired position has been selected, use the "Set" button to save the orientation to the current B-Scan Image or Video.

Transverse Probe Positions – Transverse scans provide a lateral image of the globe that traverses several clock hours. The position of the transverse scan is indicated by the center of the clock hours in the scan as well as the portion of the globe being examined (P for Posterior Pole, E for Equator, EA for Anterior to the Equator, etc.).

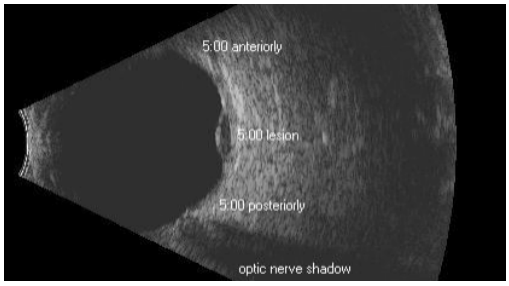
Example of 12:00 EP Scan

Image (going into screen):
Top= mid-2:00; Mid= mid-12:00; Btm= mid-10:00



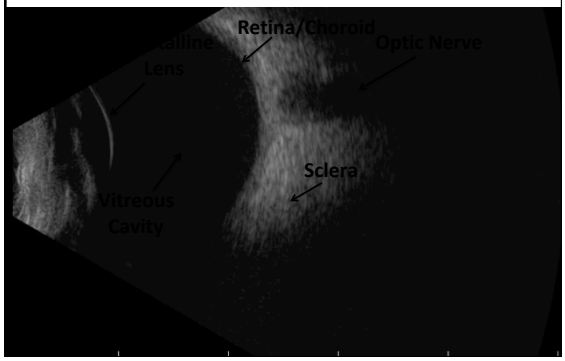
The probe is positioned on the sclera, parallel to the limbus, while the patient is looking toward the area of the eye being examined. The probe marker is held parallel to the limbus and pointed superiorly during vertical and oplique scans. For horizontal scans (6:00 and 12:00 positions), the marker is pointed nasally to keep it parallel to the limbus.

For a 12:00 EP scan, the probe is positioned at 6:00 with the marker parallel to the limbus and pointed nasally. The probe is pointed toward the Equator Posterior at 12:00.

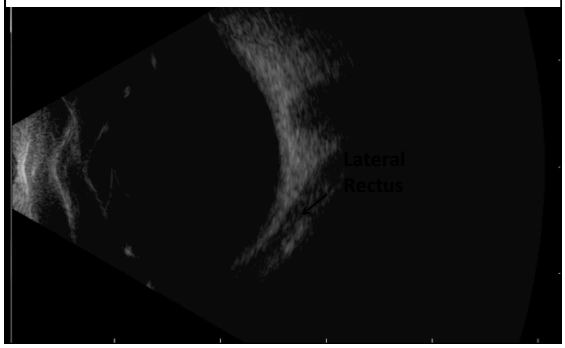


1)

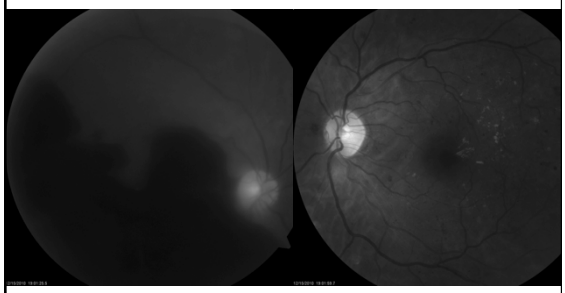
B-Scan Ocular Structures



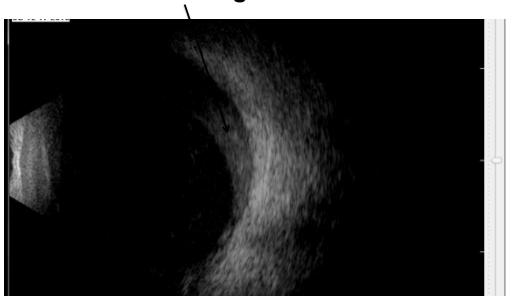
B-Scan Ocular Structures



Case 1: Vitreous Hemorrhage

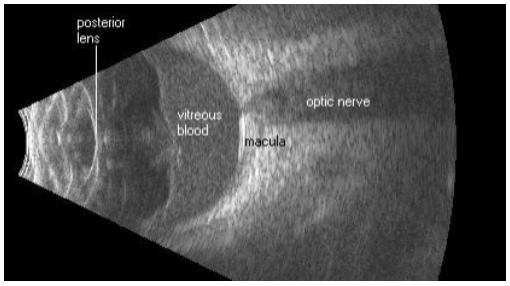


Vitreous Hemorrhage



Vitreous Hemorrhage

1)



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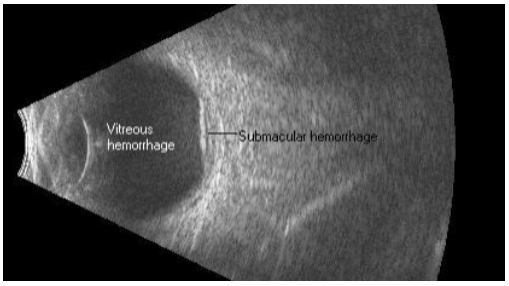
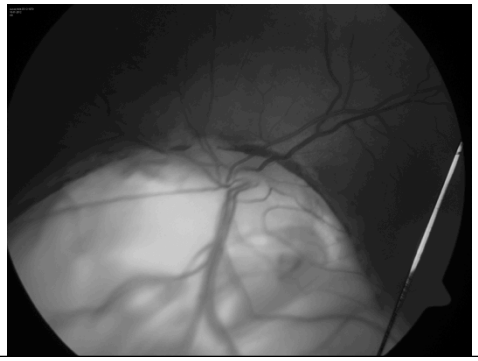
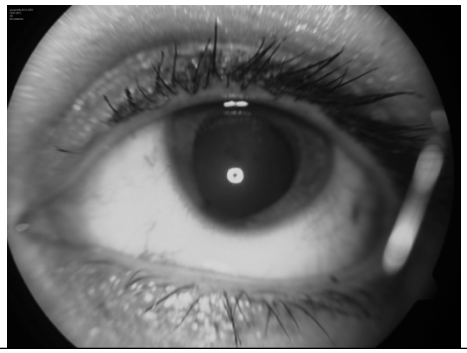


1)

Case 2:

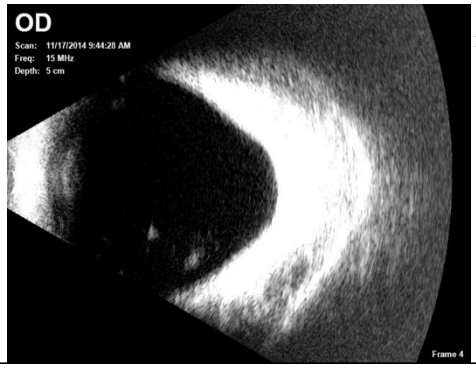




Diagnosis?

- A) Retinoblastoma
- B) Choroidal Melanoma
- C) Posterior Staphyloma
- D) Coloboma

Retinal Coloboma



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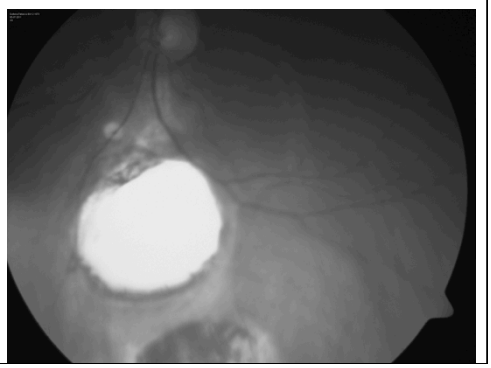
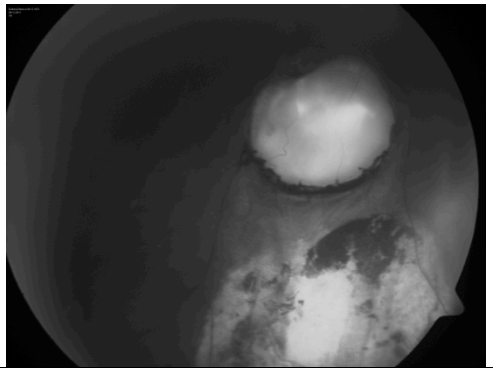
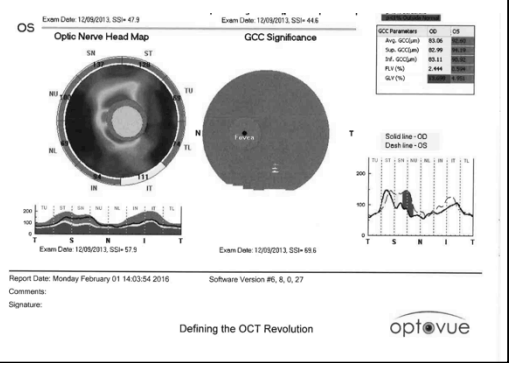
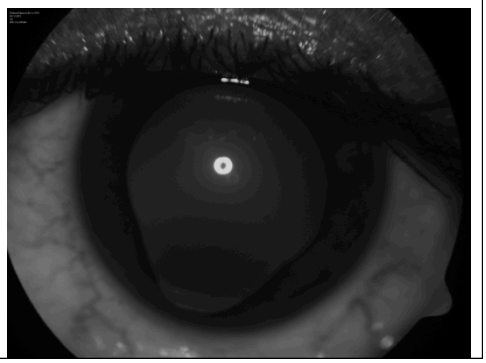
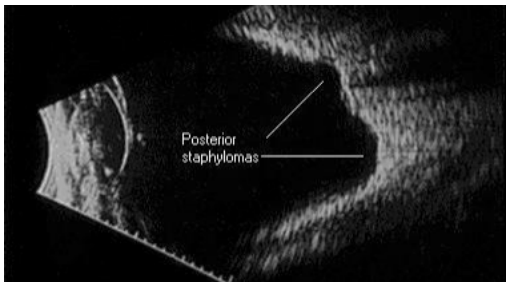
Case 3



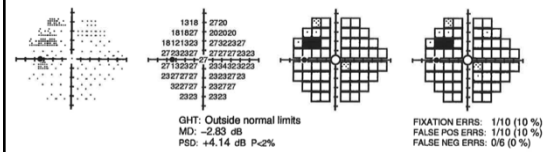



OS
Optic Nerve Head Map
GCC Significance
Exam Date: 12/09/2013, SSI= 47.9
Exam Date: 12/09/2013, SSI= 44.6
Exam Date: 12/09/2013, SSI= 57.5
Exam Date: 12/09/2013, SSI= 59.6
Solid line - OD
Dash line - OS
Report Date: Monday February 01 14:03:54 2016
Software Version #6, 8, 0, 27
Comments:
Signature:
Defining the OCT Revolution
optovue

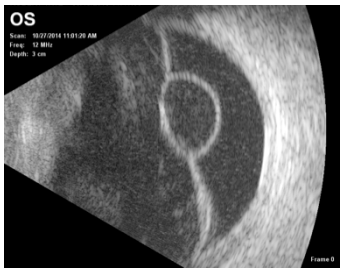



Posterior
staphylomas

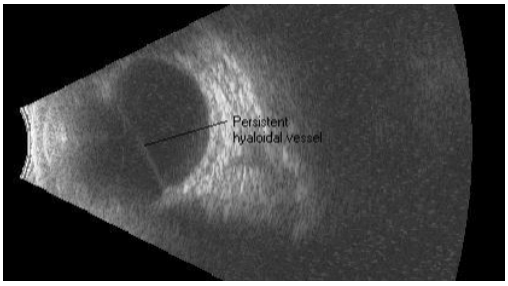
1)


GHT: Outside normal limits
MD: -2.83 dB
PSD: +4.14 dB P<2%
FIXATION ERRS: 1/10 (10 %)
FALSE POS ERRS: 1/10 (10 %)
FALSE NEG ERRS: 0/6 (0 %)

Case 4



Case 5



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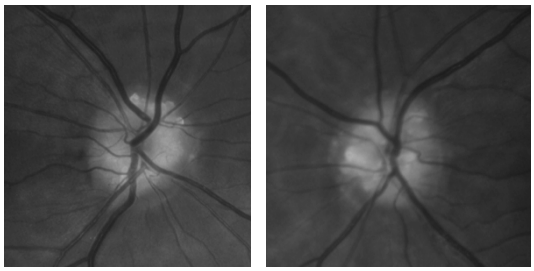
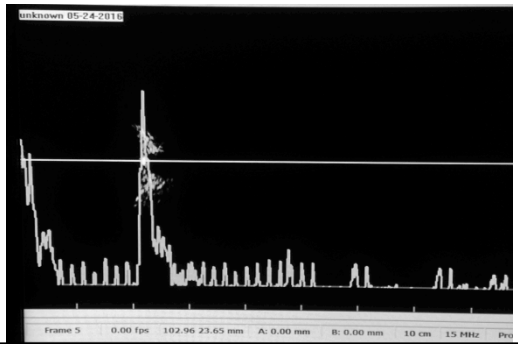
Case 6



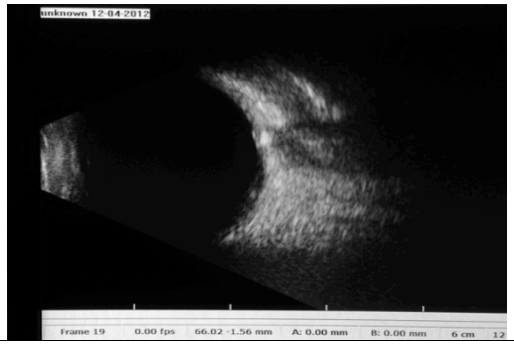
Optic Nerve Drusen or Papilledema?

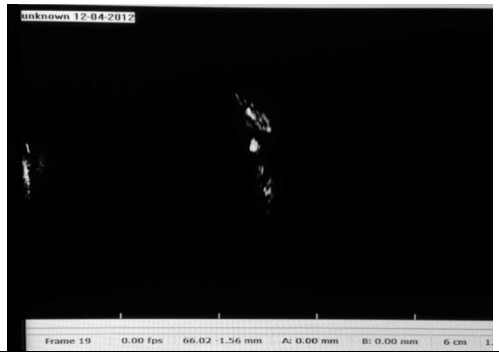
Gain Down

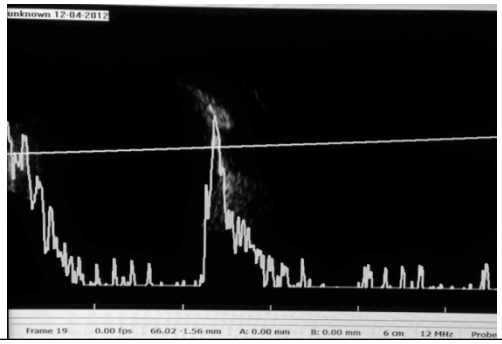
Gain Down with A-Scan Thru Drusen

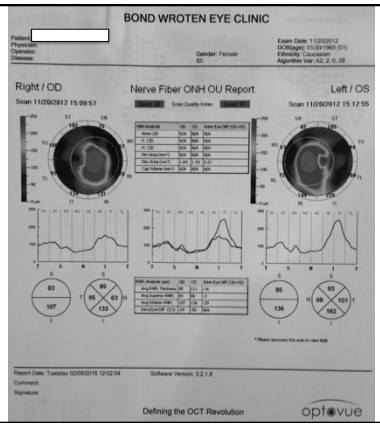


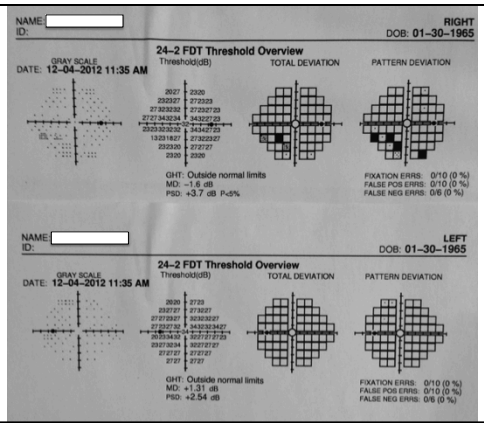
Fellow Eye



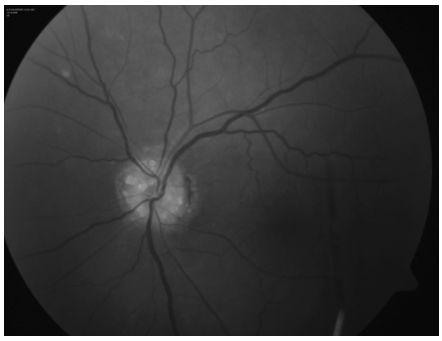


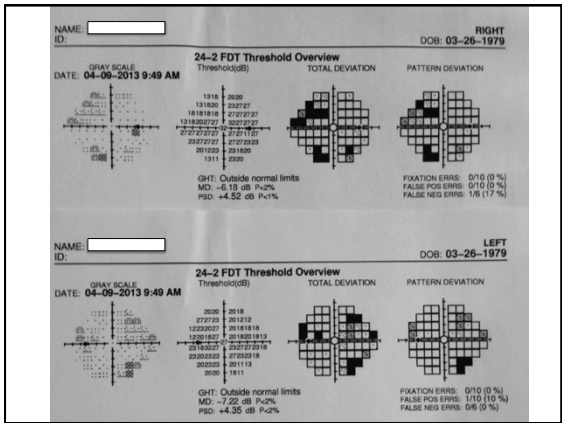


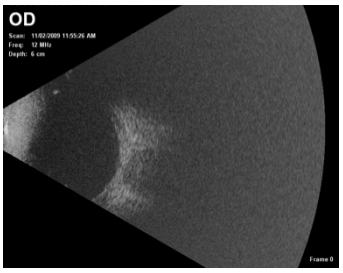


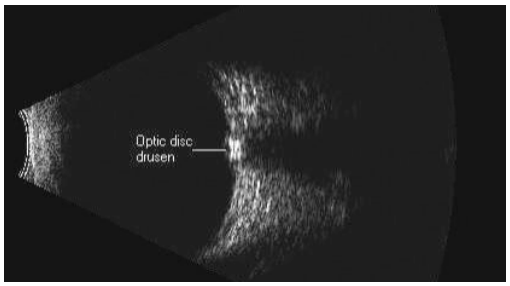


Case 7

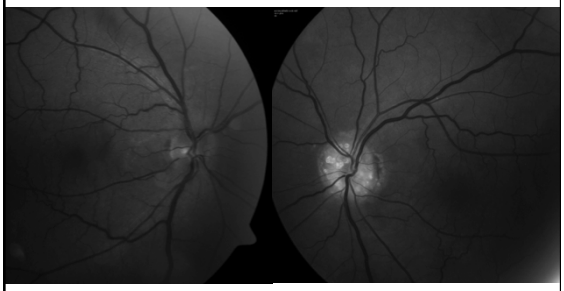


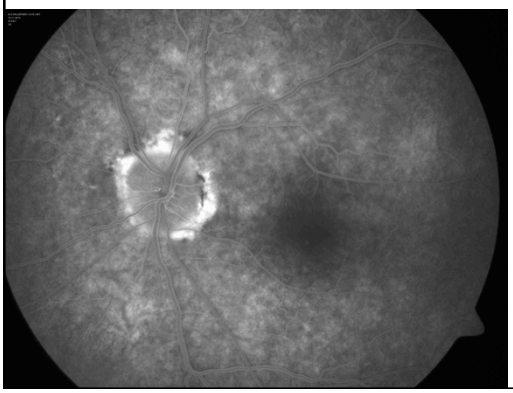

NAME:
ID:
RIGHT
DOB: 03–26–1979
24–2 FDT Threshold Overview
GRAY SCALE
DATE: 04–09–2013 9:49 AM
Threshold(dB)
TOTAL DEVIATION
PATTERN DEVIATION
GHT: Outside normal limits
MD: –6.18 dB P<2%
PSD: +4.52 dB P<1%
FIXATION ERRS: 0/10 (0 %)
FALSE POS ERRS: 0/10 (0 %)
FALSE NEG ERRS: 1/6 (17 %)
NAME:
ID:
LEFT
DOB: 03–26–1979
24–2 FDT Threshold Overview
GRAY SCALE
DATE: 04–09–2013 9:49 AM
Threshold(dB)
TOTAL DEVIATION
PATTERN DEVIATION
GHT: Outside normal limits
MD: –7.22 dB P<2%
PSD: +4.35 dB P<2%
FIXATION ERRS: 0/10 (0 %)
FALSE POS ERRS: 1/10 (10 %)
FALSE NEG ERRS: 0/6 (0 %)


OD


Optic disc
drusen

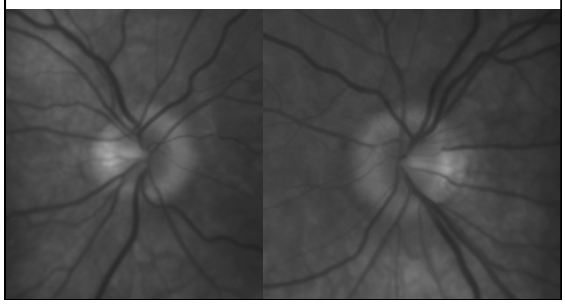
1)

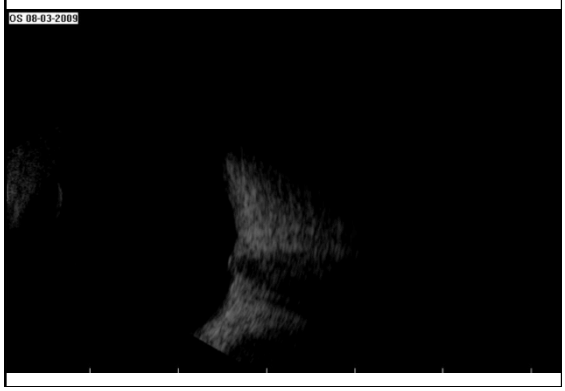


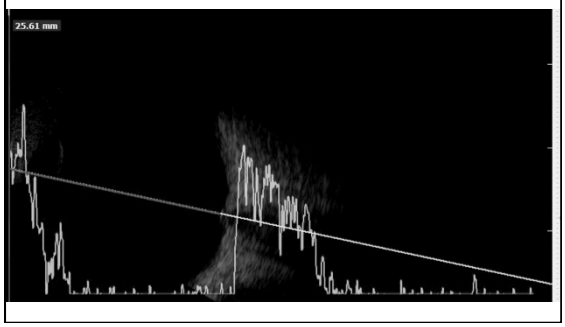


Case 8

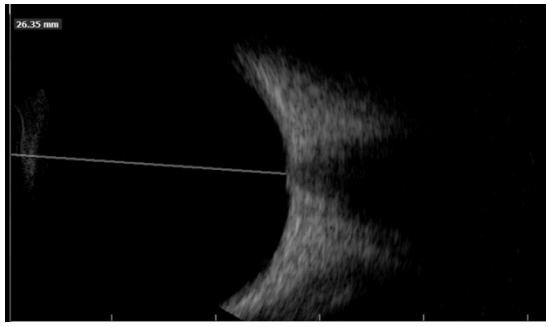
Young Adult Caucasian Female presents c/o severe headache





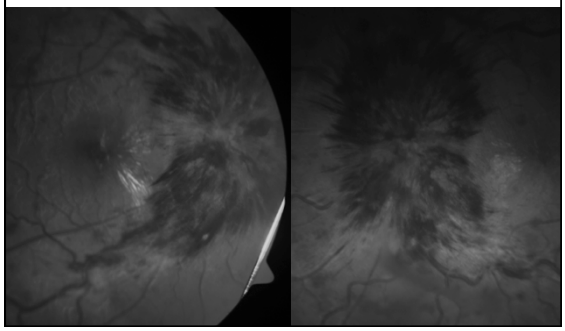


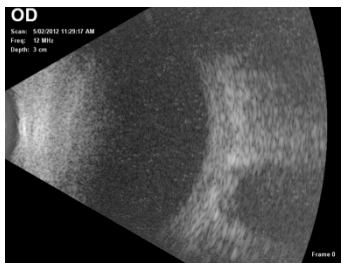
Nearly Resolved

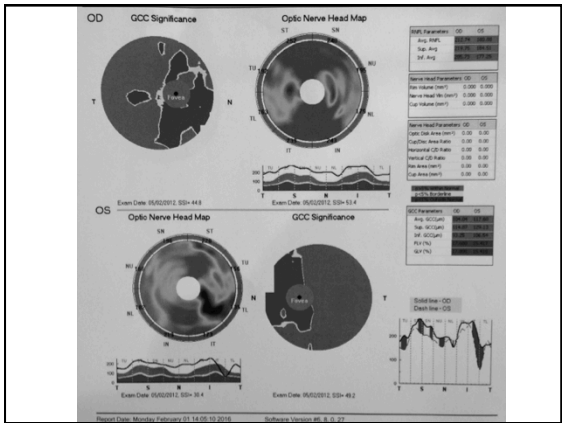


Case 9

30 YOAAF with Headache & Blurred Vision...

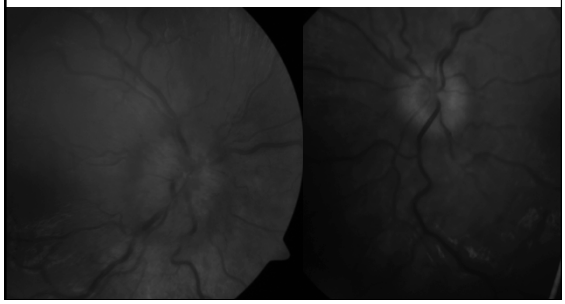


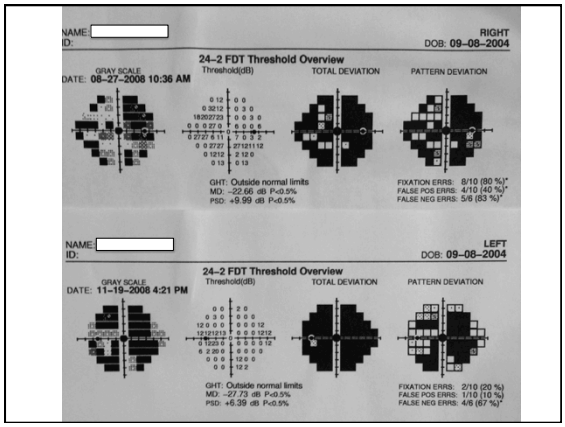


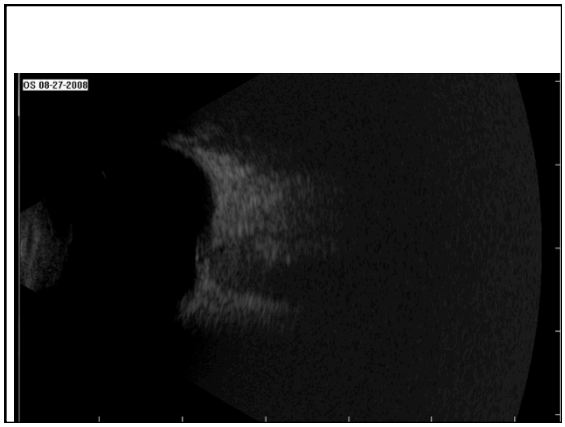


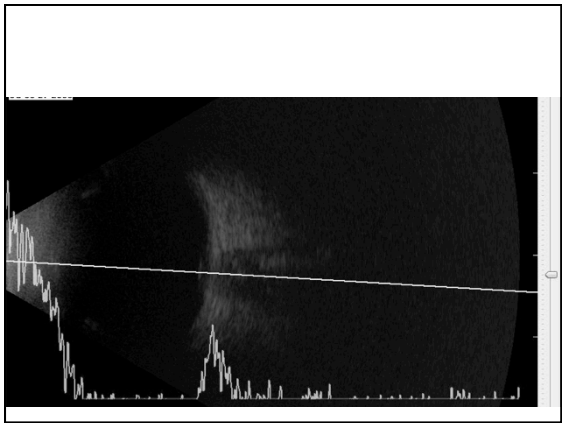
Case 10

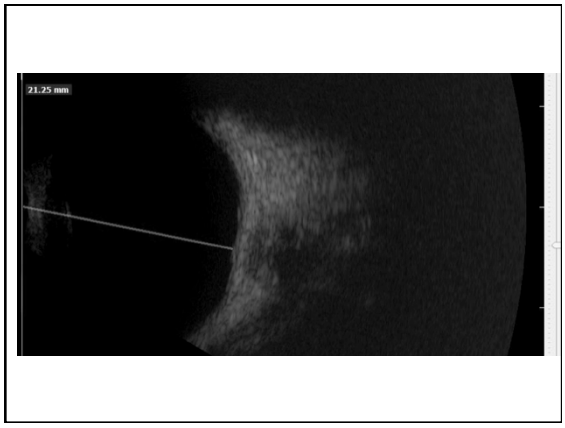
4 YOWM in for GEE while Older Sister gets CL-P
BVA ~20/25 OD, OS

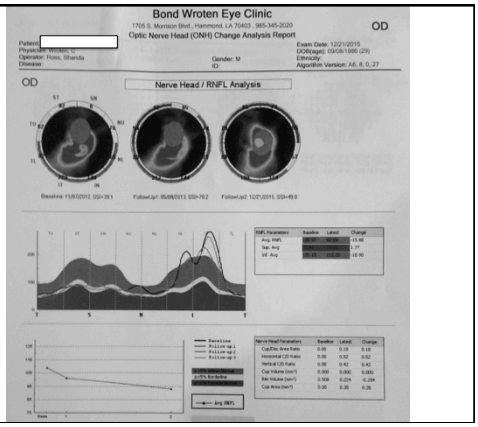




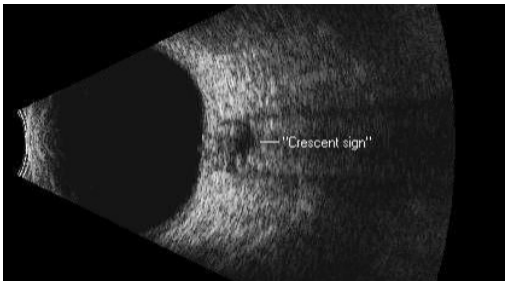








Papilledema

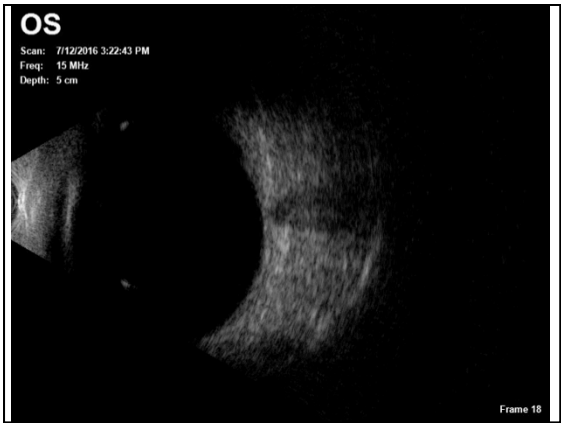


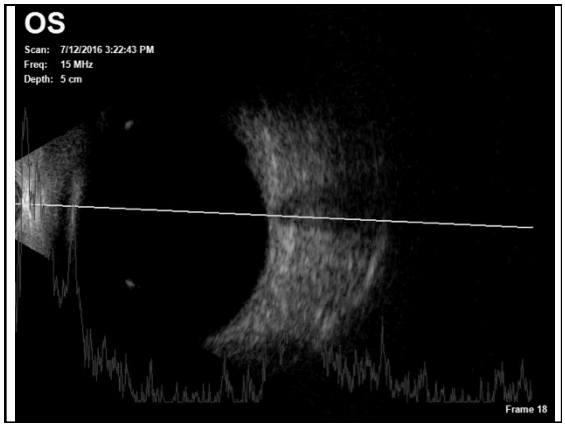
1)

30 Degree Test for Papilledema

- Perform A-Scan in Primary Gaze & measure width of Optic Nerve
- Repeat with 30° ~Gaze Shift
- If Optic Nerve Width DECREASES = PAPILLEDEMA

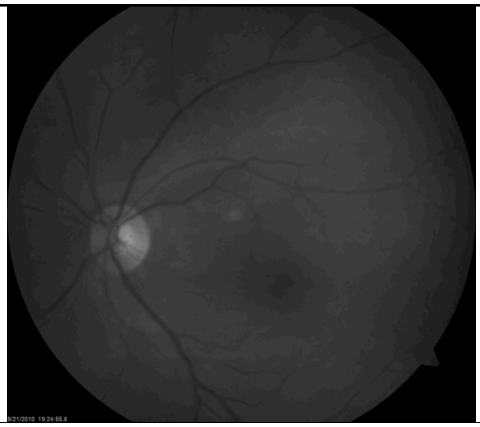
Case 11





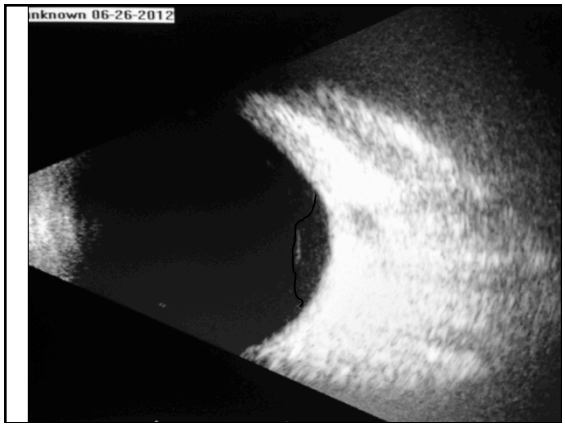
Case 12

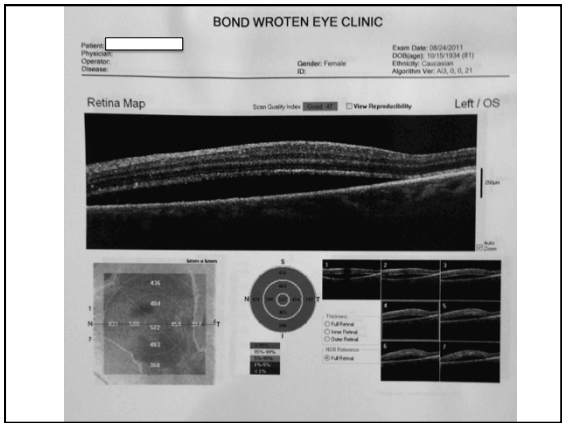
- 77 Y.O. Caucasian Female
- Comprehensive Eye Exam
- Previously told had “freckle” in OS
- BCVA: ~20/25 OD, OS
- Mild Cataracts
- Fundus...

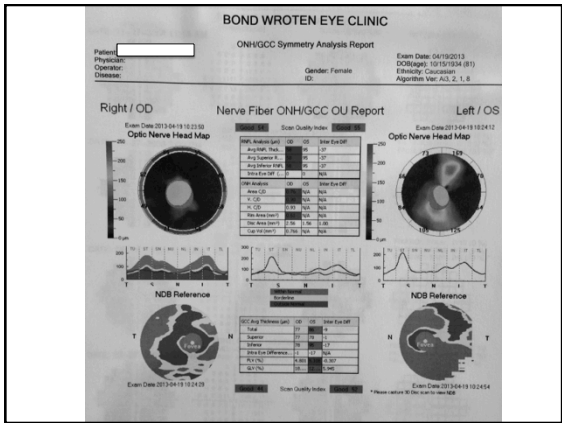


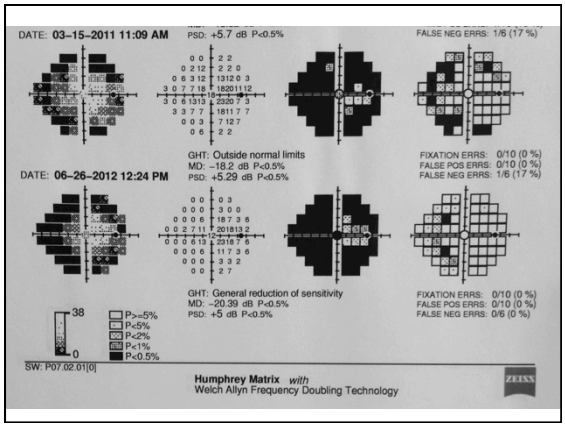
- What would you do?
  - A) RTC x 3-4 mos for repeat DFE & fundus photos
  - B) RTC x 1 yr for GEE/DFE
  - C) Consult Retina stat
  - D) Order additional testing (e.g. IVFA, B-Scan)

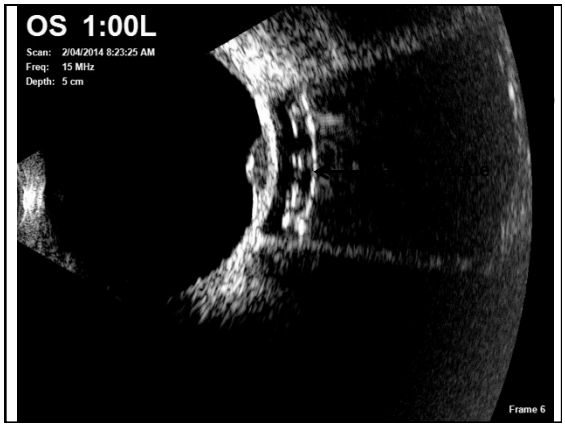
- Lost to f/u x 11 months then RTC c/o dry eyes...


Unknown 06-26-2012

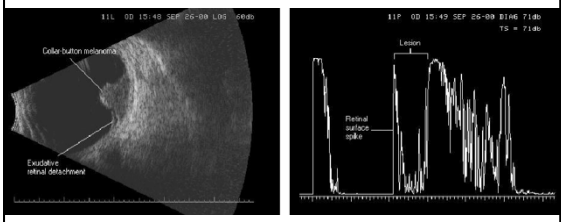

BOND WROTEN EYE CLINIC
Retina Map
Left / OS


BOND WROTEN EYE CLINIC
ONH/GCC Symmetry Analysis Report
Right / OD
Nerve Fiber ONH/GCC OU Report
Left / OS
Optic Nerve Head Map
NDB Reference


DATE: 03-15-2011 11:09 AM
PSD: +5.7 dB P<0.5%
FALSE NEG ERRS: 1/6 (17 %)
GHT: Outside normal limits
MD: -18.2 dB P<0.5%
PSD: +5.29 dB P<0.5%
FIXATION ERRS: 0/10 (0 %)
FALSE POS ERRS: 0/10 (0 %)
FALSE NEG ERRS: 1/6 (17 %)
DATE: 06-26-2012 12:24 PM
GHT: General reduction of sensitivity
MD: -20.39 dB P<0.5%
PSD: +5 dB P<0.5%
FIXATION ERRS: 0/10 (0 %)
FALSE POS ERRS: 0/10 (0 %)
FALSE NEG ERRS: 0/6 (0 %)
P>=5%
P<5%
P<2%
P<1%
P<0.5%
SW: P07.02.01[0]
Humphrey Matrix with
Welch Allyn Frequency Doubling Technology
ZEISS

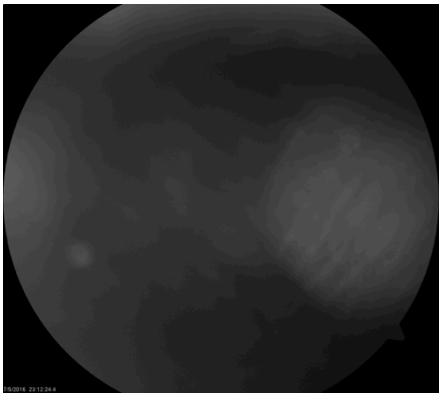

OS 1:00L
Scan: 2/04/2014 8:23:25 AM
Freq: 15 MHz
Depth: 5 cm
Frame 6

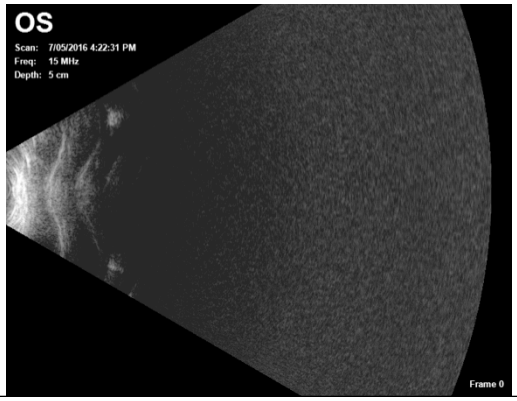
1)

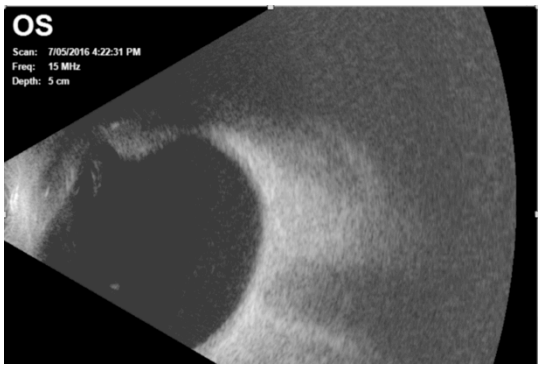


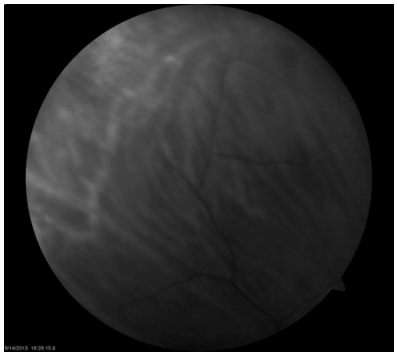
Case 13: 36 YOWF presents for CL Exam

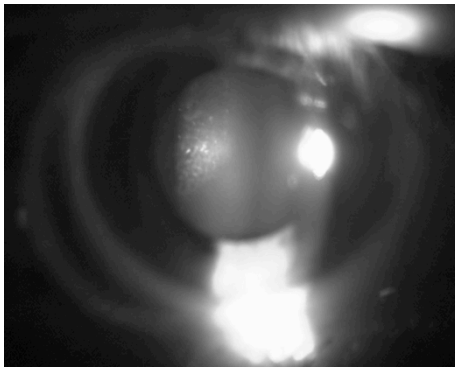
- Compound Myopic Astigmat
- History & Anterior Segment Exam Unremarkable
- Peripheral Retinal Exam...

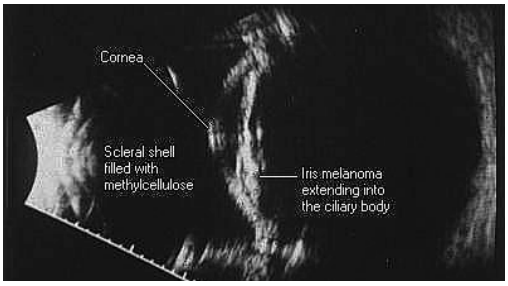




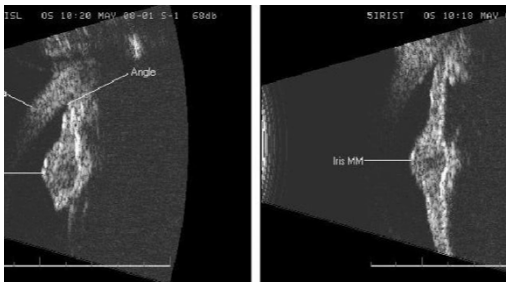




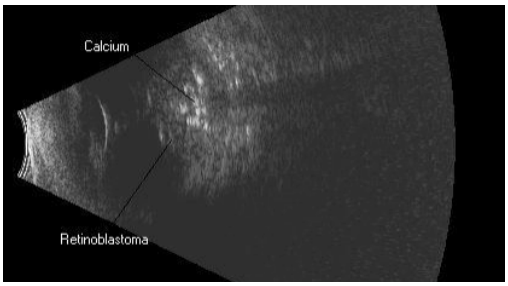



Cornea
Scleral shell
filled with
methylcellulose
Iris melanoma
extending into
the ciliary body

1)

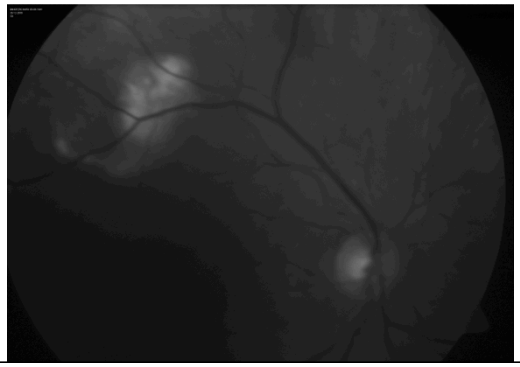

Angle
Iris MM

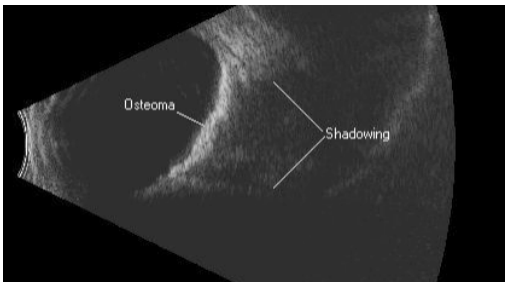
1)


Calcium
Retinoblastoma

1)

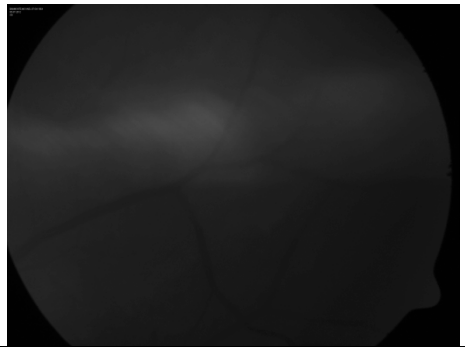
Case 14

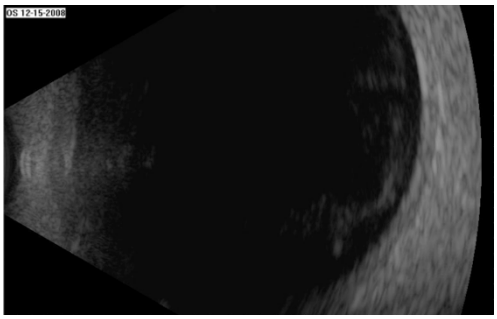



Osteoma
Shadowing

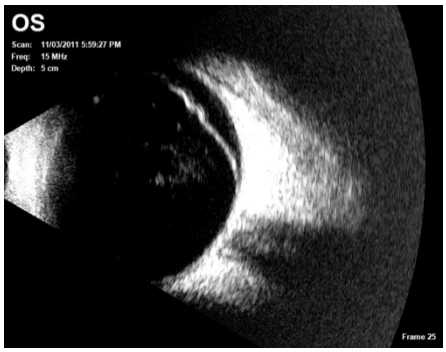
1)

Case 15



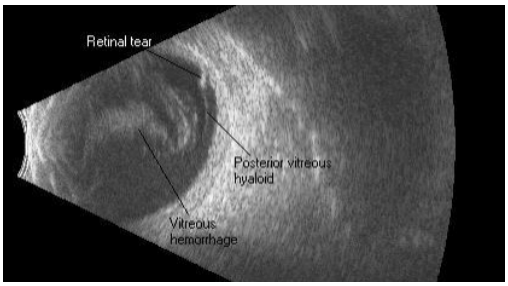


Retinal Detachment



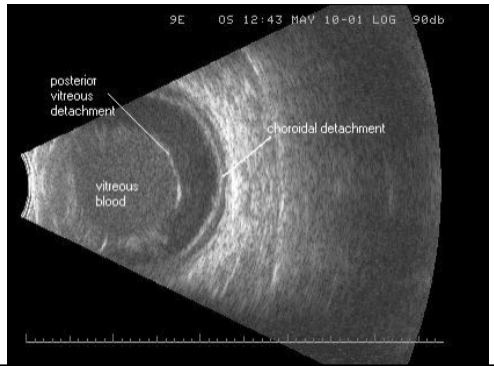
1)

Retinal Tear with Vitreal Hemorrhage



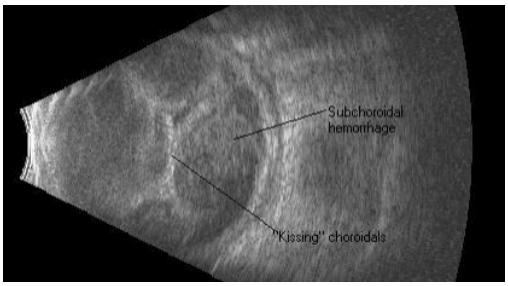
1)

PVD, Choroidal Detachment, Vitreal Heme



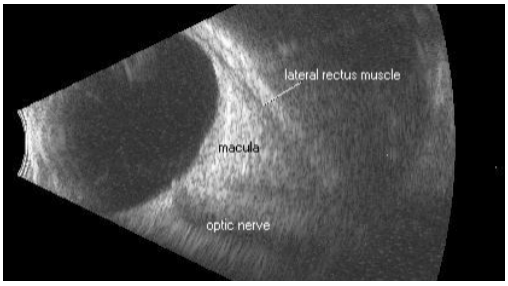
1)

Choroidal Effusion & Subchoroidal Heme



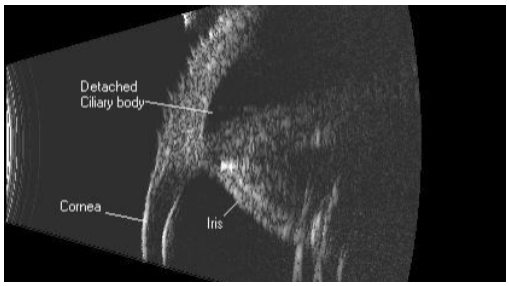
1)

Other B-Scan Findings...



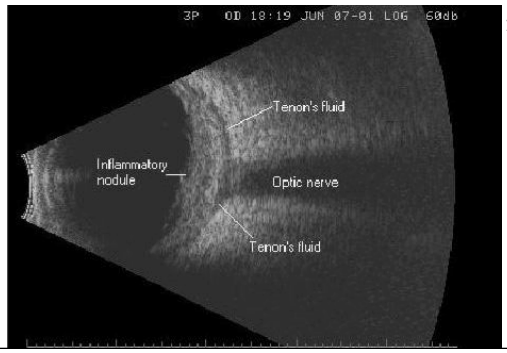
1)

Ciliary Body Detachment



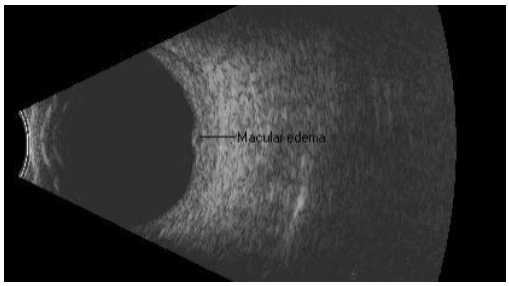
1)

Nodular Posterior Scleritis



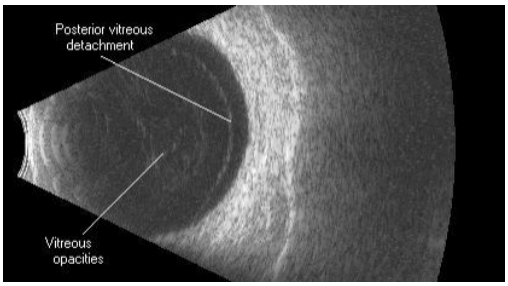
1)

Macular Edema



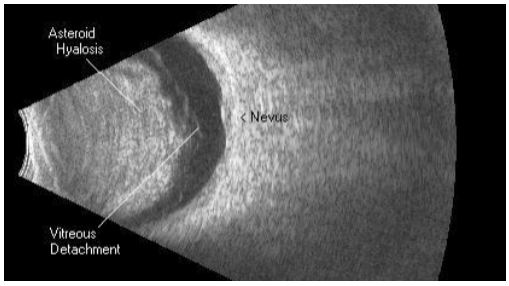
1)

PVD & Vitreal Floaters



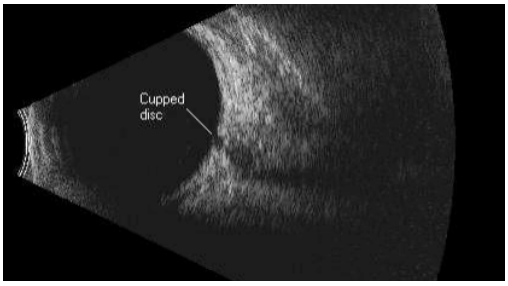
1)

PVD, Asteroid Hyalosis, & Choroidal Nevus



1)

Cupped Disc



1)

Ophthalmic Ultrasound: A-Scan Indications

- Measure axial length of the eye
- Determine IOL power
- Differentiate pathology

Ophthalmic Ultrasound: B-Scan Indications

- Severe lid edema
- Partial/total tarsorrhaphy
- Keratoprosthesis
- Corneal opacities (scars, severe edema)
- Hyphema
- Hypopyon
- Miosis
- Iridodialysis/corectopia
- Pupillary Membranes
- Dense Cataracts
- Phthisis Bulbi

Ophthalmic Ultrasound: B-Scan Indications

- Posterior Staphyloma/Coloboma
- Vitreous opacities (hemorrhage, PVD, inflammation)
- Iris Lesions (cysts, tumors)
- Ciliary Body Lesions (cysts, tumors)/Detachments
- Differentiating Intraocular Tumors
- Serous vs. Hemorrhagic Choroidal Detachments
- Rhegmatogenous vs. Exudative Retinal Detachments
- Optic Nerve Drusen vs. Papilledema
- Pseudopapilledema vs. Papilledema

Ophthalmic Ultrasound: Pachymetry Indications

- Central Corneal Thickness for Glaucoma (1 time)
- Corneal edema
  - Fuch's Endothelial Dystrophy
  - Microcystic Edema
  - Post-intraocular surgery
  - Corneal Ectasia (keratoconus, pellucid marginal degen.)
- Remember, pachymetry can performed be via ultrasound or optical method

CPT 76511: Ophthalmic ultrasound, diagnostic; quantitative A-Scan only

- Medicare/Novitas (LA) = $94.86
- BC/BS (LA) = $115.20

CPT 76516: Ophthalmic biometry by ultrasound echography, A-Scan

- Medicare/Novitas (LA) = $72.92
- BC/BS (LA) = $87.38

CPT 76519: Ophthalmic biometry by ultrasound echography, A-Scan; with intraocular lens power calculation

- Medicare/Novitas (LA) = $84.04
- BC/BS (LA) = $85.38

CPT 76513: Ophthalmic Ultrasound, diagnostic; anterior segment ultrasound, immersion (water bath) B-scan or high resolution biormicroscopy

- Medicare/Novitas (LA) = $88.33
- BC/BS (LA) = $106.61

CPT 76512: Ophthalmic Ultrasound, diagnostic, B-Scan; with or without superimposed non-quantitative A-scan

- Medicare/Novitas (LA) = $93.08
- BC/BS (LA) = $125.34

CPT 76510: Ophthalmic Ultrasound, diagnostic, B-Scan and quantitative A-scan performed during the same patient encounter

- Medicare/Novitas (LA) = $159.37
- BC/BS (LA) = $190.46

CPT 76514: Ophthalmic Ultrasound, diagnostic; corneal pachymetry, unilateral or bilateral, determination of corneal thickness

- Medicare/Novitas (LA) = $15.53
- BC/BS (LA) = $15.33

- Covered once per lifetime for Glaucoma & Glaucoma Suspect codes, and generally as indicated for corneal ectasia & edema

- NOTE: There are other specific ultrasound CPT codes, too (e.g. CPT 76529 – Ophthalmic ultrasonic foreign body localization; CPT 76970 – Ultrasound study follow-up)

Ultrasound as Treatment?!?!

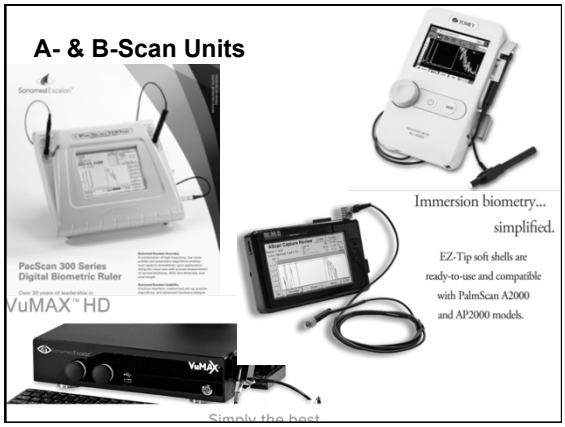
TUG (EyeSonix)

- Therapeutic Ultrasound for Glaucoma
- Low power, low frequency
- Enhances outflow
- In Clinical Trials
  Prelim: 20% IOP ↓ x 1 yr
  in 74% with elevated IOP

French co. **Eye Tech Care** developing same technology

A- & B-Scan Units

A- & B-Scan Units



IOL Master 700 (Zeiss)

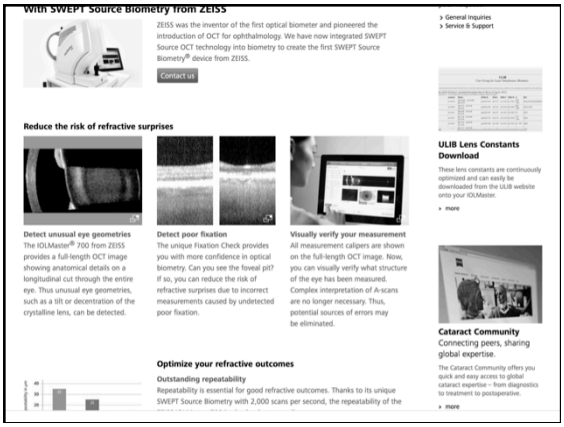
The new IOLMaster 700
Next generation biometry from ZEISS

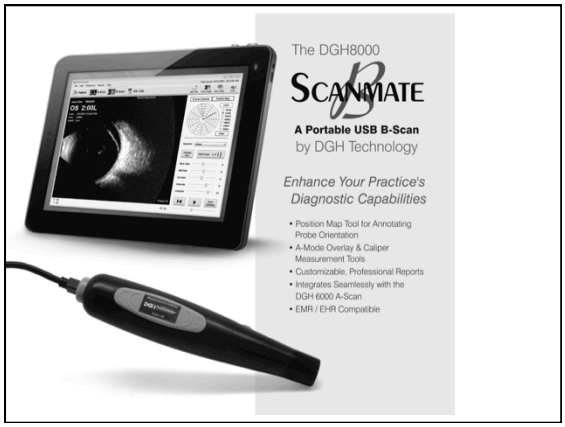
Highlights | Technical Data | Options & Accessories | Services | More Information

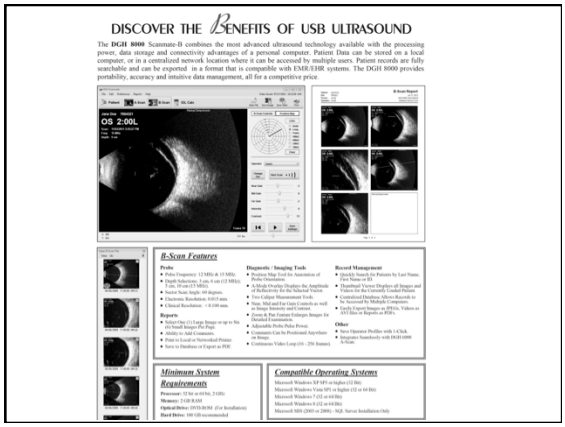
With SWEPT Source Biometry from ZEISS

ZEISS was the inventor of the first optical biometer and pioneered the introduction of OCT for ophthalmology. We have now integrated SWEPT Source OCT technology into biometry to create the first SWEPT Source Biometry® device from ZEISS.

Contact us





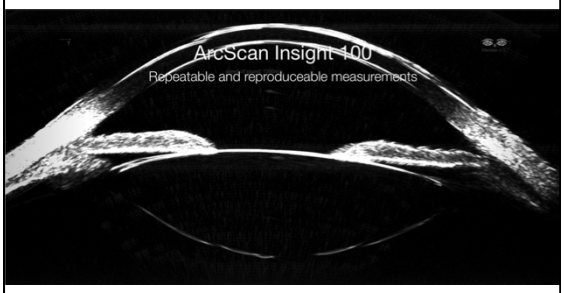


UBM Units

ArcScan Insight 100

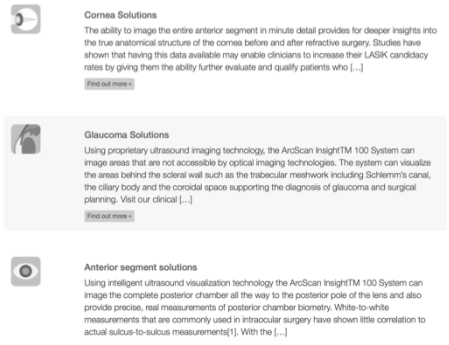
FDA Approval & CE Mark Received in Early 2016

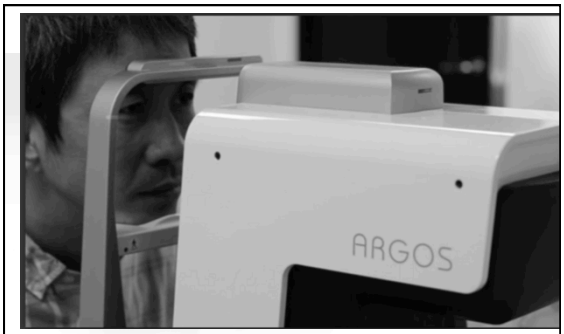
ArcScan Insight 100



2 Minute, Quasi-Noncontact Scan
High Frequency Ultrasound (20-60 MHz) = 1 µm resolution!!!

ArcScan Insight 100





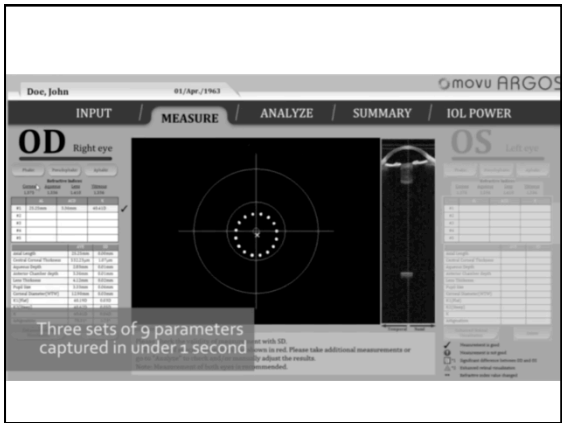
Ophthalmic Ultrasound...

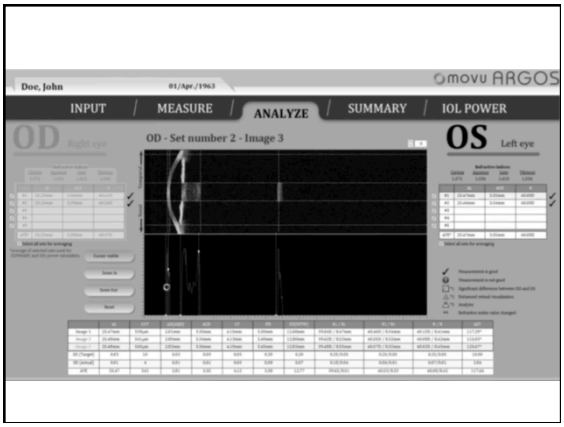
- 30 seconds to learn...a lifetime to master!

Acknowledgements, References, & Resources

1) "B-Scan Ocular Ultrasound", Rhonda Waldron & Thomas Aaberg, Jr., M.D., et al, *Medscape Online*, May 09, 2016. – background material, some A- & B-scan images
2) *DGH 6000 (Scanmate-A) Operator's Manual* – background material
3) Various manufacturer's images & websites (DGH, Quantel, Reichert, Accutome, Alcon, etc.)
4) *Ophthalmic Ultrasound: A Diagnostic Atlas, 2nd ed.*, C.W. DiBernardo & Ellen Greenberg, Thieme, 2006.
5) *The Sankara Nethralaya Atlas of Ophthalmic Ultrasound and Ultrasound Biomicroscopy, 2nd ed.*, Muna Bhende, et. al., Jaypee Brothers Medical Publishing, 2013.

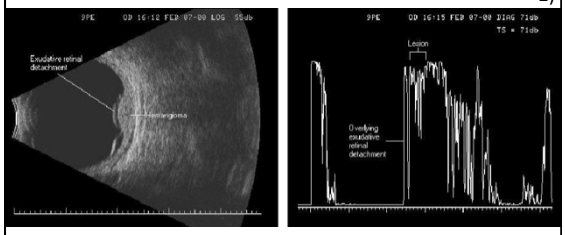
THANK YOU!





Exudative Retinal Detachment & Hemangioma

1)



Retinal Detachment with Vitreal Hemorrhage

1)