Disclosures

• Nothing related to this presentation

• Serve on the AOA Commission on Ophthalmic Standards
  • Represent AOA on ANSI Z80 and ANSI Z87
• ANSI – American National Standards Institute
• ISO – International Standards Organization
• ICNIRP – International Commission on Non-Ionizing Radiation Protection
• CIE – International Commission on Illumination
• FDA – US Food and Drug Administration
Total Eclipse

- April 8, 2024
  - 1:50pm – 4:30pm (varies by a few minutes)
  - Totality
    - Dayton 3:10 – 3:13pm
    - Dublin 3:11 – 3:15pm
    - Cleveland 3:13 – 3:17pm

- Last total solar eclipse in Ohio was in 1806

- Next one is 2099

- Solar Eclipse 2024 | Ohio Department of Natural Resources (ohiodnr.gov)
Eclipse Frequency

• Total eclipses occur on Earth ~ 18 months
• Annular eclipse ~ 2 years
• Partial eclipses ~ 2 times per year
Eclipse Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial</td>
<td>(unsafe viewing)</td>
<td><img src="image1.png" alt="Partial Eclipse" /></td>
</tr>
<tr>
<td>Annular</td>
<td>(unsafe viewing)</td>
<td><img src="image2.png" alt="Annular Eclipse" /></td>
</tr>
<tr>
<td>Total</td>
<td>safe viewing @ this moment</td>
<td><img src="image3.png" alt="Total Eclipse" /></td>
</tr>
</tbody>
</table>

August 2017

Eclipse Types: https://science.nasa.gov/eclipses/types/
Corona – no, not that one

- Iridescent crown-like ring around the edge of the moon
- Safe to view, but lasts for a few moments
- Partial eclipse just prior to totality and just after
  - This is a high risk moment for sustained viewing
Angle subtense

Normal sun appearance

Moon
- 0.5°

Sun
- 0.52°
What are we concerned about?

**UV**
- UVB and UVA
- Cornea and crystalline lens will absorb this
- Aphakia
- Non-UV IOL
- Small part of the problem

**Visible**
- High energy visible
- Blue light hazard is involved when looking at the sun

**IR**
- Near IR is transmitted to PRs and RPE
- Non-dilated state, not a problem
Eclipse related retinal damage AKA...

- Eclipse - burn, blindness, retinopathy
- Solar - retinitis, chorioretinal burn
- Foveomacular retinitis
- Photo – retinitis, maculopathy
- Photic – retinitis, retinopathy
Solar (Photic-, Eclipse-) Retinitis/Retinopathy

• Difficult to know incidence; many will not report any problems
• Individuals may wait a few days to seek care
• Symptoms:
  • Persistent after-images, reduced vision, scotoma
• Signs:
  • May not appear for a few days; likely asymmetric;
  • Yellowish-white spot near foveola
  • Imaging is required
How bright?

Source of Light

- Night Sky, 0.001
- Mesopic Threshold, 5
- Visual Acuity Screen, 100
- Smart Phone, 400
- Cloudy Sky, 2000
- Clear Sky, 8000
- Solar Disc at Horizon, 600,000
- Solar Disc, 1,600,000,000
- Slit Lamp ~10 to 30 sec
- Welding Arc 0.6 sec
- Welding Arc 0.5 sec
- Frosted Bulb, 120,000
- Fluorescent Bulb, 12,000

ICNIRP 10,000s

Blue Light Weighted Radiance W m-2 sr-1

CD/m2

- 0.001
- 0.01
- 0.1
- 1
- 10
- 100
- 1000
- 10000
- 100000
- 1000000
- 10000000
- 1E+09
- 1E+10

Damage and Comfort

Maximum Exposure
• 0.6 sec at zenith
• 2.5 sec at 10° above horizon
• Buffer of 1 log unit
  • 6 sec
  • 25 sec

17 min exposure (1,000s)
• Safety of 0.6 sec
• \( \frac{1,000}{0.6} = 1,666.67 \)
• \( \frac{1}{1,667} = 0.06\% \)
  • Four 10% mydriatics 0.01%

Sun
• 1,600,000,000 cd/m²
• 0.06% safe, but too bright
• Need 0.0006% (6 log units) for comfortable viewing
  10,000 cd/m²
Electromagnetic Spectrum
Ultraviolet (UV) Radiation
What’s visible light?

- Industry (ANSI, ISO, CIE) says 380nm
- Younger people and aphakes can see 380nm
- Health organizations: AOA, AAO, WHO – all start at 400nm
- Why the discrepancy?
Infrared (IR) Radiation
What radiation reaches the retina?
Ocular Transmittance – UV, Visible, IR

Cornea, Crystalline Lens, IOLs

Adapted from Br J Ophthalmol 2006;90:784–792
Ocular Transmittance – UV, Visible, IR


Scientific Reports | (2020) 10:16445
Vitreous & Total Eye

Fig. 6. Transmittance of the vitreous.

Boettner & Wolter IOVS Dec 1962
Light-Tissue Interactions
Absorbance
Light-Tissue Interactions

**Photochemical**
- 11-cis to all-trans retinal
- PDT
- Retinal damage

**Photothermal**
- PRP
- Grid laser
- Retinal tear repair
- ECP

**Photodisruptive**
- Excimer
- FS
- Nd:YAG
  - LPI
  - Capsulotomy
UV, IR, visible?

- UVA can play a role, but only with aphakia
- Thermal injury can occur, but not from IR – rather it would be visible
  - Thermal injury during an eclipse only with dilated pupil or with telescope/binoculars
  - 3mm pupil, calculated temperature rise is 2-4°C
IR
Infrared (IR) Radiation

• IR-A 780 – 1400nm
  • Retinal burns (visible to ~1400nm)

• IR-B 1400 – 3000nm

• IR-C 3000 – 10,000nm
  • Corneal burns (3000 to 10,000nm)

• Thermal skin burns can occur at any wavelength

Cataract – 800 to 3000nm
## IR - Procedures

<table>
<thead>
<tr>
<th>Nd:YAG</th>
<th>Femtosecond</th>
<th>Retinal Lasers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 1064nm</td>
<td>• 1053nm</td>
<td>• Most are visible</td>
</tr>
<tr>
<td>• Photomechanical</td>
<td>• Photomechanical</td>
<td>• Usually near IR (810nm)</td>
</tr>
<tr>
<td>• Converged laser</td>
<td>• Converged laser</td>
<td>• Transpupillary Thermotherapy (TTT)</td>
</tr>
<tr>
<td>• Capsulotomy</td>
<td>• Applications</td>
<td>• Long exposure 1min</td>
</tr>
<tr>
<td>• LPI</td>
<td>• LASIK flap</td>
<td>• Low irradiance</td>
</tr>
<tr>
<td></td>
<td>• FLACS</td>
<td>• Used for small tumors</td>
</tr>
<tr>
<td></td>
<td>• SMILE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• PK</td>
<td></td>
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<tr>
<td></td>
<td>• DALK</td>
<td></td>
</tr>
</tbody>
</table>

[https://doi.org/10.1016/j.sjopt.2014.09.001](https://doi.org/10.1016/j.sjopt.2014.09.001)
IR Damage to the Eye

**Cornea**
- Thermal burns
  - >1400nm
- Photomechanical
  - Converged laser

**Cataract**
- Epidemiological data
  - Steel workers
  - Glass blowers

**Eclipse**
- Likely not involved with eclipse retinopathy
- Could be with a dilated pupil

IR in Ophthalmic Procedures

- Imaging
  - OCT, auto-refractor, meibography,
- Retinal lasers
  - Photothermal; deep retina
- LLLT
- IPL
UV Damage to the Eye

Overall
- Acute
  - Photokeratitis
  - Maculopathy?
- Chronic
  - Pinguecula
  - Pterygium
  - Climatic droplet keratopathy
  - Nuclear cataract
  - AMD?
  - Eyelid cancers¹

Common UV Sources
- Sunlight
- Tanning beds
- Germicidal devices
- Welding
- Water treatment
- Night clubs?
- Excimer
- Cross-linking

Reminders about UV
- Grass reflects 2-5%
- Water 3-13%
- Snow 94%
- Every 1000ft is a 4% increase in UV
  - Mountaineering
  - Skiing

Chronic UV Exposure

Eyelid, Conjunctiva
- Pterygium “surfer’s eye”
  - Incidence 1 to >30%¹
  - Meta-Analysis 10%²
  - UV 43% attributable risk³
- Pinguecula
  - Prevalence 22.5 to 97%⁵
  - UV⁴

Climatic Dropout
‘Environmental Sub-Epithelial Keratopathy’⁶
- Incidence varies depending on climate
  - Dry, arid
- Diet
  - Insufficient in ascorbic acid (Vit C)
  - Protects against UV damage
  - Suppress gelatinases
- Sun protection

Cataract
- Chesapeake Bay Watermen study⁷
  - Assoc. w/ cortical cataract
- Beaver Dam Eye Study⁸
  - Assoc. w/ cortical cataract
- Blue Mountains Study¹⁰
  - Cataract often occurs infra-nasal (Coroneo effect)⁹


https://doi.org/10.1111/aos.12628
Photo-(solar-, photic-)keratitis

Keratopathy
• Depends on wavelength and duration
• Cornea heavily absorbs 280-300
  • If dose is significant then:
    • ROS develop
    • Disrupt DNA
    • Disrupt cellular membranes
    • Protein disruption

Sources
• Germicidal lamps
  • OCULAR IMMUNOLOGY AND INFLAMMATION 2021, VOL. 29, NO. 1, 76–80
• Night Clubs
  • Contact Lens and Anterior Eye 39 (2016) 316–317

Management
• Artificial Tears
• Ab ung
• Combo drop
• Time (2-3 days)
UV Ophthalmic Procedures

**Excimer Laser**
UVC = 192nm

**Cross Linking**
UVA = 370nm

**Light Adjustable IOL**
UVA = 365nm (FDA approval 2017)

- Start @ 3 weeks post-op
- 3 treatments 48 hrs apart
- Up to 3DC; 2D sphere
## Devices

### Sunglasses
- FDA Class I Medical Device
  - Exempt from 510k
- 100% blocking UVA and UVB
- Some argue <1% transmission to 400nm

### Contact Lenses
- Class I
  - More than
    - 90% UVA (316-380)
    - 99% UVB (280-315)
- Class II
  - More than
    - 50% UVA
    - 95% UVB

### HEV?

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**OptiBlue™ Light Filter**

60% blue violet light filter, highest in the industry™.

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**UV Blocking HEVI Filtering**

Class I UVA Blocking: Works within 50% of UVA and >95% of UVB rays.

HEV: Absorption: Filters >95% of high energy UVB + UVA light (316-400 nm) with 20% wavelength range.
Other considerations with UV

Medications (some)
- Doxycyline
- Levofloxacin
- Bactrim
- Accutane
- Thiazides
- NSAIDS
- Amiodarone

Children

Outdoor Activities
- Skiing
- Water
- Climbing
- Significant time outdoors

UV to HEV & the Retina
Outer Retinal Layers  Ophthalmology 2014;121:1572-1578
Welding

Ocular Risks

- Photokeratitis
- Case
  - 47yo male
  - 10-15min unprotected exposure
- Maculopathy
  - Likely due to intense short visible wavelengths

Phototoxic Maculopathy
BMJ Case Rep 2019;12:e227677

16 months post-incident
20/100 BCVA

Normal
Photochemical retinal damage

Reversible

Adaptive
Oxidative stress
Neuronal dysfunction
Photoretinitis

Early Pathology
Oxidative stress
Neuronal & vascular dysfunction

Late Pathology
Irreversible
Oxidative stress
Neuronal & vascular dysfunction
Neuronal loss
Functional loss
Photoretinopathy

Smoking, light, age, obesity
Deposits
Lipid accumulation
Photostasis
Higher metabolism
ROS
Bruch's membrane
RPE
Photoreceptors (outer segments)

Oxidative stress
Neuronal dysfunction
Reversible
Irreversible

Adapti ve
Earl y Pathology
Late Pathology
Macular Degeneration and UV/Visible

- Not proven, mixed findings
- Most large epidemiologic studies show no relationship between exposure and AMD
- Recent meta-analysis (14 studies) concluded that sunlight may not be associated with an increased risk of AMD
- “Blue-blocking” IOLs were not protective vs “non-blue” blocking IOLs (meta-analysis, cohort)
- Likely due to inflammatory cascades, vasculopathic, oxidative stress, genetics, poor cellular support systems

HEV– IOLs and AMD


Taiwan
- 186,591 patients (2008-2013)
  - 21,126 BF IOL
  - 165,465 non-BF IOL
- 6.1 year f/u (1-10 range)

Hazard Ratio
- Dry 0.95 (0.88-1.03)
- Wet 0.96 (0.77-1.18)

Cochrane Database Syst Rev. 2018 May 22;5(5):CD011977
- 51 RCTs
- At least 1 year f/u
- BF IOL vs non-BF IOL
- Acuity, progression of AMD
- Unclear whether BF-IOLs preserve macular health


Finland
- 11,397 patients
  - 5,425 BF IOL
  - 5,972 non-BF IOL
- 50-55 month f/u

Hazard Ratio
- Wet 1.08 (0.8-1.47)
Blue Light Hazard – what is it?

Peaks at 440nm in phakic eye

Aphakia UV hazard

How was this determined?

- Brilliant light sources with prolonged exposure
- Irradiances were a million times higher than normal indoor or outdoor exposures
- Should only be considered if staring at the sun or welding arcs or prolonged time with surgical lamp


Am J Ophthalmol 2022;240: 51–57
High Energy Visible (HEV)

Is it blue?
Is it violet?
Violet-blue?
Blue-green?

**HEV**

**Good for:**
- Rods
  - Helps with night vision
  - Falls
- IPRGCs
  - Melanopsin
  - Sleep cycles
  - Better physical and mental health
- Life

**When to Mitigate**
- At night
  - For circadian rhythm

**Summary**
- HEVs is good
- Should be mitigated at night
- Inconclusive evidence for AMD
- HEV CLs
  - Can help with visual comfort and glare

Griepentrog et al., iScience 24, 102009
January 22, 2021

OVS 2020;97:207 - 217
Eclipse Cases and Precautions
Disease Process

- Patients will seek care 1-3 days after event
- Mild to moderate reduction in VA
- Localized scotoma or persistent after-image
- Yellow spot at foveola
- Outer retinal disruption on OCT
  - Cysts, hyper-reflective signal, hyperfluorescence at fovea with FANG
- Retinal signs tend to improve over weeks to months
  - VA often improves but may be permanently reduced
• The Lancet 2001;357:199-200
• 45 people in UK sought care
  • 20 had visual symptoms
    • 5 had retinal changes (ages 18-52 years)
    • at 7 months 12 of 16 had resolution of symptoms
  • 4 could detect changes
Utah 2017

- Surveys sent to 38 (92%) of OMDs in Utah
  - 27 patient reports
  - 6 had retinal findings
- 17yo male, reported 15s of viewing 20/25 OD, 20/20 OS

Clinical Ophthalmology 2018:12 1853 –1857
OCT

- Hyper-reflective band from inner retinal to RPE
- Outer retina is universally involved
- 21 year old – viewed annular eclipse unprotected several times, a few seconds each view
Viewing Sunsets

- 43 year old male
- Watched sunsets for years with no eye protection
- 20/30 OD, 20/50 OS

DOI:10.1056/NEJMicm2215436
Other Imaging

FAF

FANG

Adaptive Optics

RETINA 29:1340–1345, 2009

JAMA Ophthalmol 2018;136(1):82-85
Precautions / Recommendations

• Do not view with an unprotected eye
• Do not use binoculars or telescopes unless proper filters are in place (decreases image size – increases irradiance)
• Large pupils (eg dilation) increase risk
• The only time to view the eclipse unprotected is during the totality phase of a total eclipse (do not view annular eclipse)

• Eclipse glasses should comply with ISO 12312-2 labeling
Transmittance of Devices

• ISO 12312-2
  • 0.0032% OD 5 (upper limit; lower limit 0.000061%)
  • 0.00044% OD 6 comfortable viewing
  • Still not safe to use binoculars or telescope

• Mydriatic specs 10%
  • Stack 6 (OD 6), 7 still visible

• Welder Masks
  • Shade #12 – 14
  • 0.0032% (OD5) to 0.0003% (OD6)
Resources

- https://eclipse.aas.org/eye-safety
- https://science.nasa.gov/eclipses/safety/
- https://ema.ohio.gov/media-publications/ohio-total-solar-eclipse
Thank you

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