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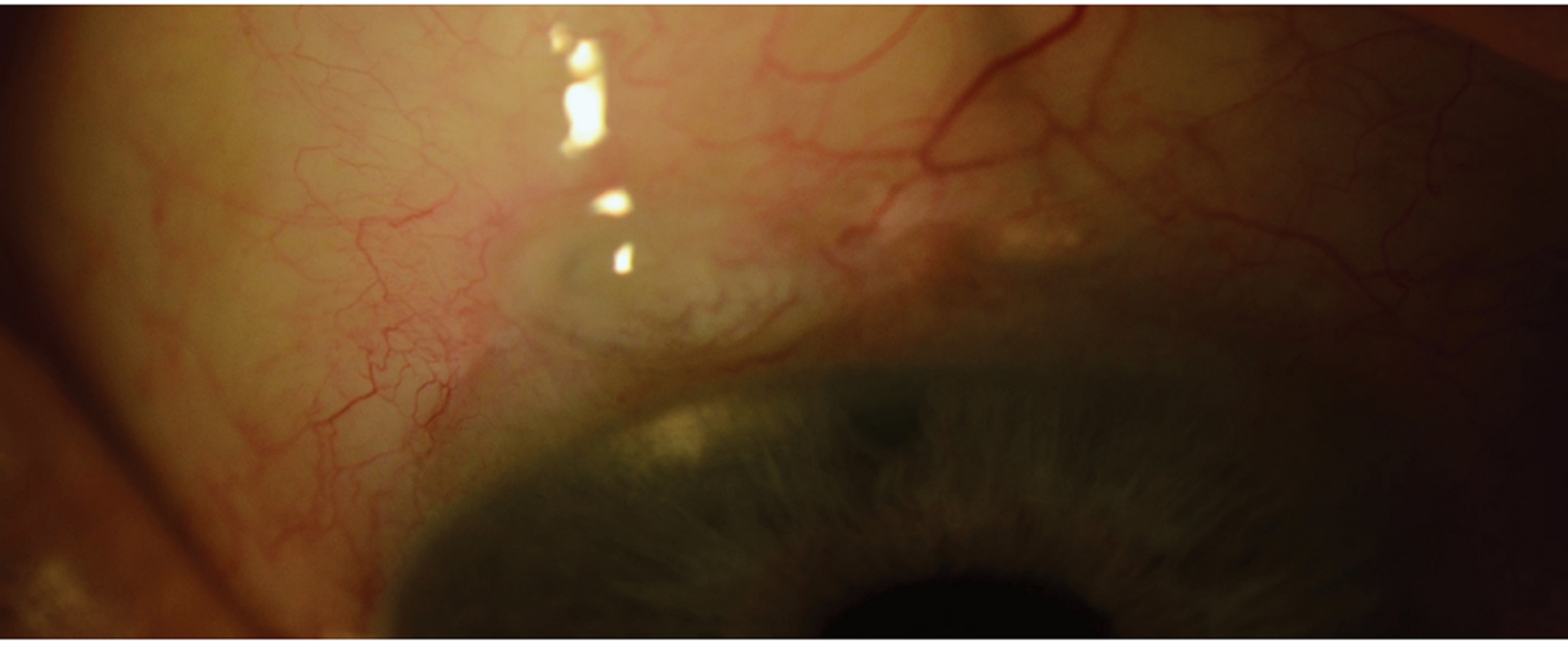



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# Students Increasingly Affected by Anxiety, Depression

Aurora Denial, OD, FAAO | Optometric Education: Volume 45, Number 2 (Winter-Spring 2020)

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*Aurora Denial, OD, FAAO*

Anxiety and depression are apparently on the rise among students at various education levels. The Pew Research Center reported in 2019 that 70% of teens say anxiety and depression are major concerns among their peers.[1] According to the American College Health Association's National College Health Assessment II, in 2016 nearly two-thirds of college students reported anxiety, which was an increase of 50% over the previous five years.[2]

Depression and anxiety seem to be on the rise among graduate healthcare students as well, including optometry students. I've had informal discussions with colleagues in a variety of healthcare professions, and all report seeing an increase in student anxiety and depression at their institutions. Published data support these impressions. A meta-analysis by Quek et al. showed a high prevalence of anxiety among medical students globally, ranging from 29.2% to 38.7% compared with 3% to 25% in the general population.[3] According to data collected for a study done by The Ohio State University, 17% of incoming students in seven disciplines (dentistry, medicine, nursing, optometry, pharmacy, social work and veterinary medicine) reported moderate to severe depressive symptoms, 14% reported moderate to severe anxiety, and 6% reported suicidal ideation."[4] Risk factors or predictors for anxiety and depression identified by the researchers included lack of sleep, lifestyles behaviors, general health, perceived lack of control and stress.[4]

**Defining Anxiety and Depression**

Anxiety as defined by the American Psychological Association (APA)[5] is "an emotion characterized by feelings of tension, worried thoughts and physical changes like increased blood pressure. People with anxiety disorders usually have recurring intrusive thoughts or concerns. They may avoid certain situations out of worry. They may also have physical symptoms such as sweating, trembling, dizziness or a rapid heartbeat." The APA[6] characterizes depression as "more than just sadness" and states "People with depression may experience a lack of interest and pleasure in daily activities, significant weight loss or gain, insomnia or excessive sleeping, lack of energy, inability to concentrate, feelings of worthlessness or excessive guilt and recurrent thoughts of death or suicide."

**Why are Students Struggling to Cope?**

Why do we have a generation of students who seem to have very little ability to cope with stress? Certainly healthcare education is academically and emotionally challenging. In graduate health programs, students must master a large quantity of information, develop clinical skills, pass formalized tests and deal with difficult emotional topics and patient scenarios. Additionally, students at the graduate level are often living on their own, dealing with financial issues and having to adjust to a prescribed academic schedule. It is not surprising that the stress inherent in graduate education may worsen pre-existing mental health issues.

Researchers have hypothesized that academic pressure, the use of electronic devices and social media may be contributing to the rise in anxiety and depression.[2] However, previous generations all had academic pressure to succeed. Although the use of social media and electronic devices has definitely influenced this generation, I find it difficult to believe that it is significantly responsible for these trends. Have parenting styles changed so that children are no longer required to deal with small stresses that would enable them to develop coping skills? As parents are we nurturing coping skills in our children or are we solving problems for them and protecting them from any stressful situation? College environments used to prepare students both academically and emotionally for the adult world. However, students now report that in many instances there is great flexibility in college and very few consequences for underperformance.

Stress is a normal component of everyday life and definitely a component of graduate education. Should institutions screen for anxiety and depression following admission? This would allow for early identification and possible treatment. As faculty, we are all concerned about this trend.

* * * * *

ASCO posted a podcast on this topic, an interview with Jonathan Peretz, PsyD, a student wellness expert. Dr. Peretz talks about stress among students and strategies for handling it, including mindfulness and self-care and how to know when professional help is needed. Listen here.

* * * * *

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# Application of an Online Homework Tool in Optometry for Geometric Optics Improves Exam Performance

Varuna Kumaran, MS, B.Optom, Krishna Kumar, B.Optom, MPhil, PhD, and Naveen Mahesh, B.E. | Optometric Education: Volume 45, Number 2 (Winter-Spring 2020)

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**Background**

Online homework has been replacing traditional paper-based homework in many fields, including chemistry, statistics, physics, accounting and mathematics; however, its impact on exam performance is ambiguous. While improvements have been observed in many studies,[1-24] other studies show little or no improvement.[25-32] Regardless, students and faculty have shown a strong preference for online homework systems.[1-32] Students receive feedback on their homework performance instantly and automatically as practice problems are completed, which lowers the burden of evaluation for faculty members.[8,15,21]

The use of technology in optometric education is becoming more common. Recently, a study compared the use of digital assessments with paper-based tests in geometric optics.[33] The creation of an online problem set for optics was also reported, but the report did not discuss its use by students.[34] There are no publications to date that describe the effectiveness of online homework systems in the field of optometry.

This research paper describes the use of an online homework system — Kognify (Kognify Assessment and Skill Development, PL, Chennai, Tamil Nadu, India) — for training students of optometry in the Geometric Optics-II (GO-II) course. In previous semesters, 15- to 30-minute paper-based quizzes were used to assess GO-II students' knowledge of the subject matter. The quizzes were conducted weekly during the 2.5- to 3-hour class periods. Each quiz assessed knowledge of the concepts that had been covered in the previous class. A teaching assistant evaluated the answer sheets within the following week. Any individual or common mistakes were discussed on a later date. This method was time-consuming but used because more practice for problem-solving and application of concepts was crucial at this early stage of learning. Students in these previous semesters felt the need for more faculty guidance in solving problems, but extra class hours could not be allotted due to time constraints. To address these concerns, Kognify was employed in 2016.

Kognify is an online homework application.[35] Many school systems use Kognify in high school education.[35] The faculty create a database of multiple-choice questions in Kognify along with topics and objectives that can be tagged to their questions. Students can access Kognify through the Google Chrome or Firefox web browsers or an Android app for mobile use. Groups of questions are presented randomly as "workouts" that are given to students on a regular basis. Faculty can customize the number of questions in a workout, the time limit and the number of workouts per week. Faculty monitor performance in terms of accuracy and response time. A report is generated and shared with each student for every topic. Concepts are then reinforced as needed during class time via student-teacher interactions.

We tested whether Kognify would improve exam performance compared with employing regular weekly quizzes. This paper reports data that support the efficacy of Kognify in improving exam performance scores in the GO-II course in optometry.

**Methods**

The study was conducted at the Elite School of Optometry, Chennai, Tamil Nadu, India, which is affiliated to Birla Institute of Technology and Science, Pilani, Rajasthan, India. The study compared two groups of students. The first group took GO-II in July to December of 2015 (CO2015). CO2015 consisted of 31 students (10 males and 21 females), ages 17-19 years as of January 2015 (mean age ±SD = 18.08 years ±0.41). The second group of students took GO-II in July to December 2016 (CO2016). CO2016 consisted of 34 students (9 males and 25 females), ages 17-19 years as of January 2016 (mean age ±SD = 17.98 years ±0.5). Note that South Asian Indian optometry students are younger than their North American counterparts because optometric education is an undergraduate degree program in India. However, the syllabi for geometric optics courses do not substantially differ between the two types of programs. The syllabi for the Geometric Optics-I (GO-I) and GO-II courses taught at Elite School of Optometry, Chennai, are shown in **Appendix A**.

Both CO2015 and CO2016 had the same syllabus, and the same faculty members taught their theory classes for both the GO-I and GO-II courses. Both classes went through the university-mandated continuous assessment process during the semester.

This consisted of three evaluation components (EC1, EC2 and EC3), a comprehensive exam and a practical exam. **Table 1** shows the breakdown of the total course grade. EC1 and EC3 were paper-based class assessments on topics covered for that month alone. EC2 (a mid-semester exam) and the comprehensive exam were scheduled written exams that covered topics taught up to those points. A common examination format was followed for all the semesters for EC2 and the comprehensive exam as suggested by the institution **(Table 2)**.

**TABLE 1**
**Continuous Evaluation Process and Score Distribution**

| Component | Date, 2016 | Pattern | Total Score (150) |
|---|---|---|---|
| EC1 | August | Class assessment | 10 |
| Mid-Semester Exam (EC2) | Sept. 26 | 2 hours, written | 30 |
| EC3 | October | Class assessment | 10 |
| Practical Exam | Nov. 18 | Lab practical | 50 |
| Comprehensive Exam | Nov. 28 | 3 hours, written | 50 |

*EC = evaluation component*

***Table 1.*** *Click to enlarge*

**TABLE 2**
**General Guidelines for Framing EC2 and Comprehensive Exam Question Papers**

| |
|---|
| Make sure all chapters are covered |
| Give more weight (60%) to "must know" |
| At least 25% of the question paper can carry analytical/problem-solving/indirect questions |
| **EC2 Question Paper Pattern:**<br>Duration – 2 hours<br>Multiple-choice questions – Total score 10<br>Short answers & descriptive – Total score 50 |
| **Comprehensive Exam Question Paper Pattern:**<br>Duration – 3 hours<br>Objective – Total score 40<br>Short answers & descriptive – Total score 60 |

*EC2 = evaluation component 2*

***Table 2.*** *Click to enlarge*

The CO2015 students were trained using frequent in-class quizzes as described above. For the CO2016 students, Kognify was used as a replacement for the in-class quizzes.

*Implementation of Kognify workouts for GO-II*

Each CO2016 student was given a free password-protected user account. An initial training session on use of Kognify was given at the premises on July 18, 2016. Students were invited to perform timed workouts two to five days per week from July 19 to Sept. 16, 2016. Faculty added multiple-choice questions on a regular basis and tagged the questions with their topics and learning objectives. Five to 10 questions formed a part of each workout. The questions, as well as the answer choices, were randomized. The questions reflected topics covered in the class that week (every Monday). The concepts and problem-solving techniques delivered in the class were therefore revisited through the workouts.

**TABLE 3**
**Repeat Workouts**

| Workout No. | Workout Topic | Date, 2016 | Average Performance (%) | No. of students |
|---|---|---|---|---|
| 6 | Thick lens | July 28 | 20 | 1 |
| 7 | Thick lens | July 28 | 60 | 3 |
| 8 | Thick lens | July 28 | 60 | 6 |
| 9 | Thick lens | July 28 | 83.33 | 1 |
| 10 | Thick lens | Aug. 10 | 60 | 4 |
| 24 | Thin lens eye models | Sept. 6 | 75 | 1 |
| 26 | Revision exam | Sept. 8 | 87.5 | 1 |

***Table 3.*** *Click to enlarge*

Students with Android phones performed the workouts through their phones, while the rest used laptop or desktop computers. The students could log-in multiple times in each workout and had the option of re-attempting questions until they submitted the workout or the time expired. The time allotted for the workouts was liberal. Students were allowed to refer to books. Individual doubts were clarified via e-mail and WhatsApp messaging. The students were aware of their scores via the summary reports generated in their individual user accounts. Once most of the students had completed a workout, the assessment with the answer key was e-mailed to them for future reference. The students were encouraged and reminded to take these workouts, but no incentives were given to students to complete the workouts. The compliance and performance in these workouts were not considered toward the final scores in any way.

If a student wanted a repeat workout due to absence, a power outage, accidental logout or any other reason, it was arranged for them. If the faculty felt that unusually less time was taken, or a workout was badly performed (less than 50%), a repeat workout for only those students was arranged. The repeat workouts consisted of the same assignment, but the questions and answer choices were randomized. Workouts could be repeated only once. **Table 3** provides details regarding the number of students who took repeat workouts. Before the mid-semester exam (EC2), a review workout was given for practice.

Students used Kognify from mid-July to mid-September 2016 until the comprehensive mid-semester exam (EC2), which included subject matter covered for EC1 (involving significant mathematical calculations, formulas and important concepts) **(Table 4)**. Kognify was not employed prior to the end-of-semester comprehensive exam.

The Institutional Review Board (IRB) considered the study proposal and declared it exempt from a formal IRB approval.

**TABLE 4**
**Kognify Workouts for Geometric Optics-II: Topics and Class Averages**
**July '16 - Sept. 16, 2016**

| Workout No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Date, 2016 | July 18 | July 19 | July 19 | July 20 | July 20 | July 25 | July 26 | July 27 | July 28 | July 29 |
| Topic | Geometric Optics-I | Revision of Geometric Optics-I | | | | Thick lens | | | | |
| Class Average (%) | Trial | 61 | 70 | 61 | 64 | 74 | 62 | 58 | 69 | 62 |
| No. of Students | 34 | 34 | 34 | 34 | 34 | 34 | 33 | 32 | 34 | 33 |

| Workout No. | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|
| Date, 2016 | Aug. 1 | Aug. 2 | Aug. 4 | Aug. 8 | Aug. 9 | Aug. 10 | Aug. 11 | Aug. 12 | Aug. 17 |
| Topic | Gaussian system & eye models | | | Cylinders | | | | | Eye models |
| Class Average (%) | 62 | 77 | 64 | 74 | 69 | 68 | 63 | 67 | 69 |
| No. of Students | 33 | 33 | 33 | 33 | 32 | 32 | 32 | 31 | 30 |

| Workout No. | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|
| Date, 2016 | Aug. 19 | Aug. 22 | Aug. 23 | Aug. 29 | Aug. 31 | Sept. 1 | Sept. 7 | Sept. 16 |
| Topic | Prisms | Thin-lens eye models | | | | | Revision exam | Astigmatism & magnification |
| Class Average (%) | 71 | 62 | 76 | 72 | 61 | 73 | 78 | 66 |
| No. of Students | 29 | 31 | 31 | 26 | 26 | 28 | 24 | 21 |

***Table 4.*** *Click to enlarge*

*Statistical analysis*

Data analysis and plotting of graphs were performed using the statistical package RStudio, (R version 3.3.2, The R Foundation for Statistical Computing).[36] The normality of the data distribution was tested using the Shapiro-Wilk test. First, GO-I scores for each of the classes were compared to establish a similar academic ability between the classes. The EC2 and comprehensive exam were compared for the GO-I course for CO2015 and CO2016 using the Mann-Whitney U test. Then, GO-II scores for the mid-semester exam (EC2) and final comprehensive exam for CO2015 were compared to those for CO2016 using the Mann-Whitney U one-sided test. It tested the alternative hypothesis that the GO-II scores of CO2016 were better than the GO-II scores of CO2015. A p-value of 0.05 was considered statistically significant in all analyses.

EC1 and EC3 were not separately analyzed because they were not assessed in a structured and common examination format across classes and semesters. Practical exam scores were also not compared separately.

**Results**

Because many scores in CO2016 were not normally distributed, nonparametric statistics were used. Normality was tested using the Shapiro-Wilk normality test for the comprehensive exam and EC2 (mid-semester exam) across all semesters. Distributions deviated from normality for the comprehensive exam ($W=0.916$, $p=0.01209$) for GO-I in CO2016. EC2 ($W=0.911$, $p=0.009$) for GO-II in CO2016 also lacked normal distributions.

The academic skills of CO2016 and CO2015 were similar, as confirmed by the absence of statistically significant difference in their GO-I scores [Mann-Whitney U test: EC2 exam (Med. diff.=0 marks, $W=468.5$); comprehensive exam (Med. diff.=3.50 marks, $W=500.5$); $p>0.05$ (not significant) in both the cases]. **Table 5** summarizes the means, standard deviations, medians and 95% confidence intervals for the mid-semester exam (EC2) and comprehensive exam scores in GO-I and GO-II for CO2015 and CO2016.

**TABLE 5**
**Mid-Semester Exam (EC2) and Comprehensive Exam for GO-I and GO-II: CO2015 vs. CO2016**

| Evaluation Component | Statistic | GO-I (marks) | | GO-II (marks) | |
|---|---|---|---|---|---|
| | | Batch CO2015 (n=31) | Batch CO2016 (n=34) | Batch CO2015 (n=31) | Batch CO2016 (n=34) |
| Mid-Semester Exam, EC2 (30) | Mean ± SD | 21.03±4.49 | 21.48±4.24 | 21.21±4.56 | 23.48±4.45 |
| | Median | 21.50 | 21.50 | 21.375[#] | 24.00 |
| | 95% CI of median | (18.5, 24.5) | (19.13, 23.88) | (19.13, 23.63) | (21.25, 26.25) |
| Comprehensive Exam (50) | Mean ± SD | 32.01±7.39 | 38.78±5.91 | 31.45±8.31 | 39.77±4.77 |
| | Median | 34.00 | 37.50 | 32.50[###] | 39.813 |
| | 95% CI of median | (29.00, 36.25) | (36.50, 39.38) | (27.07, 37.25) | (38.50, 43.63) |

*Mann-Whitney U test: Difference between GO-I scores of CO2015 and CO2015 not significant at p=0.05. Mann-Whitney U test: Difference between GO-II scores of CO2016 and CO2015 significant at p<0.05[#], p<0.0001[###].*

*GO-I = Geometric Optics-I; GO-II = Geometric Optics-II; EC = evaluation component; CI = confidence interval; SD = standard deviation*

***Table 5.*** *Click to enlarge*

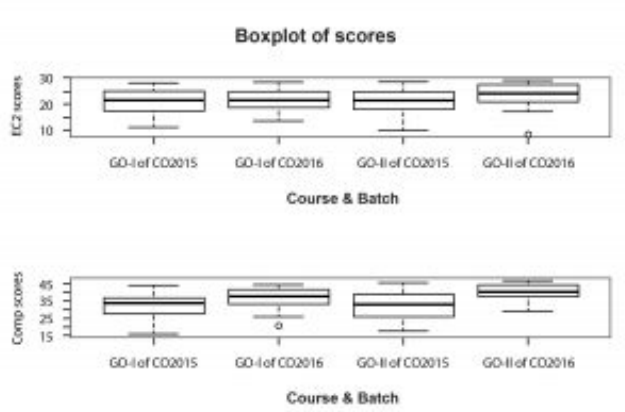


***Figure 1.*** *Mid-semester exam (EC2) and comprehensive exam (Comp) Scores in Geometric Optics-I and Geometric Optics-II for CO2015 and CO2016. Click to enlarge*

**Figure 1** presents the box plots for scores obtained in GO-I and GO-II for both classes. Better scores are seen in the class that used Kognify compared with its CO2015 counterpart that used conventional practice methods [Table 5: Mann-Whitney U test: EC2 exam (Med. diff.=2.63 marks, W=369, p=0.0193); comprehensive exam (Med. diff.=7.31 marks, W=210, p<0.0001).

**Discussion**

The results of the study suggest that Kognify improved students' performance over the conventional method of weekly on-paper quizzes. This is evident from the performance of the CO2016 students on their GO-II exams, which was much better when compared with the performance of the CO2015 students.

Concepts and problem-solving skills acquired in the GO-I and GO-II courses lay a strong foundation for other subjects such as visual optics, contact lenses, optometric optics, dispensing optics and low vision aids. Thus, reviewing concepts and practicing solving problems are essential. Remote faculty interaction with Kognify makes these goals achievable outside of time-constrained classroom hours. Apart from setting up the workouts and reviewing performance reports daily or weekly, faculty communicate with students individually about needed areas of improvement via email, SMS and WhatsApp. This further reduces dependency on additional teaching staff, who may instead be trained to set up Kognify workouts and analyze students' performance.

Kognify provides instant feedback, a feature of great benefit to students and teachers, as with other online homework systems.[8,15,21,27,39-41] In addition, Kognify provides a summary report of student performance across all topics covered. Feedback from Kognify coupled with off-line comments from faculty increased student motivation to study, as reported by students during informal conversations with faculty.

Kognify also helps to build rapport between faculty and students. Students who were generally hesitant to seek help in the classroom were given a platform from which to reach out to faculty or peers on a regular basis. Such benefits of online homework systems have been reported previously as well.[4,5]

Adoption of Kognify for the current study went smoothly except for a couple of instances. One student forgot her password and it had to be reset. Also, despite several reminders, 50% of the students (17 of 34) missed one or more workouts. One student didn't use the system fully due to health issues and completed only 9 of the 27 workouts. Students who missed two or fewer workouts had better scores on the mid-semester (EC2) and comprehensive exams, but this negative correlation is weak (p=-0.24, Spearman's rank correlation) **(Figure 2)**. Many factors influence performance on exams; therefore, additional studies can be conducted to identify the population, based on skill and motivation level, that will benefit most from online homework.

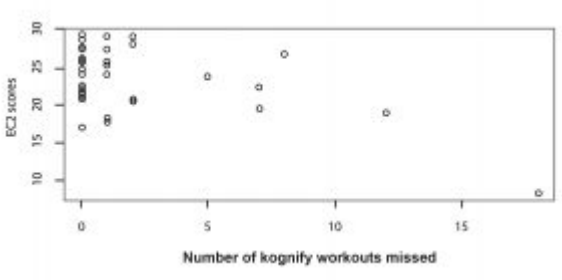


***Figure 2.*** *Scatter plot showing Geometric Optics-II mid-semester exam (EC2) scores for batch CO2016 vs. number of Kognify workouts missed. Click to enlarge*

In the current study, the students were given the liberty of multiple logouts and repeat tests. Although encouraged to take workouts without any help, they had the opportunity to re-learn a concept and re-do a question. Each student has a different learning strategy, which can influence performance on exams. Future studies can evaluate the effect of study habits (e.g., average time spent on workouts, number of repeat attempts and performance on online workouts) on final exam performance, as has been done elsewhere.[43-45]

The students were initially highly motivated to perform the Kognify workouts, but participation dropped over the weeks. With the burden of other subjects and activities, they needed more reminders to complete their tasks. Nevertheless, the minimum compliance was 61% (21 of 34 students participated across all workouts). To make students more participative, timely completion of Kognify workouts and scores in the workouts can be considered in determination of final grades, as suggested elsewhere.[46-48] Further, if students bear the cost of the Kognify subscription, better compliance may be expected. Dedication and motivation level of faculty members, teaching assistants and students are important to the success of online homework systems, as reported earlier.[4,13,49]

Although this study took a quasi-experimental approach, it can pave the way for future prospective, randomized, controlled studies. A questionnaire to gauge students' satisfaction with Kognify would be useful in the future.

## Conclusion

This study suggests that online homework systems such as Kognify can be effective in training optometry students in problem-solving skills for geometric optics courses. Kognify can be useful for students facing qualifying exams, fellowship exams and board exams. As experienced in this study, Kognify can help faculty to plan classroom time to review concepts taught earlier and to clarify student questions before proceeding to the next lecture. It can also help students better understand the concepts with well-planned workouts that can be used anywhere, anytime.

## Acknowledgments

We thank Sarala Arumugam for creating the user accounts and providing technical support for this project. We also thank the students in the class of 2013-2017 for their valuable feedback that prompted the study, the 2014-2018 students whose data were used in the analyses, and the 2015-2019 students who used Kognify.

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**Disclaimer**

Naveen Mahesh is the founder of Kognify Assessment and Skill Development, PL. While he was instrumental in providing the idea for this study, he was not involved in the data collection and analyses for the study. Execution of the study, including creation of the questions database and collection and analyses of data, was independent of any influence from the Kognify company. Varuna Kumaran and Dr. Krishna Kumar had no financial agreement with Kognify Assessment and Skill Development, PL, to conduct this study.

Appendix A
Syllabi for Geometric Optics-I and Geometric Optics-II Courses

Geometric Optics-I

1. Introduction to light and theories of light. Wave theory – plane wave and spherical waves; definition of a ray; wavefronts – spherical and plane wavefronts. Relationship between wavefronts and converging and diverging rays. Relationship between refractive index, speed of light in different media.
2. Rectilinear propagation of light – Shadows. Real and virtual objects. Real and virtual images. Object space and image space. Conjugate points and reversibility of light path. Concepts of amplitude, intensity and phase. Optical path length. Fermat's Principle
3. Derivation of laws of reflection. Types of reflection, namely, specular and diffuse reflection.
4. Refraction; derivation of Snell's law. Glass slab; deviation produced by a glass slab. Refraction at air-liquid boundary; apparent depth; determination of refractive index of the liquid. Total internal reflection; critical angle; mirage; optical fibers.
5. Vergence; step along and step back vergence. Optical objects and images. Conjugate points. Refraction at a spherical surface; paraxial approximation. Refractive power of the surface; primary (first, front) and secondary (second, back) focal lengths; vergence equation; lateral magnification; Newton's formula.
6. Definition of a thin lens; vergence equation; Newton's formula; imaging by convex and concave lenses; changes in the position of image with changes in the position of the object.
7. Thick prism; deviation; angle of minimum deviation; dispersion – wavelength dependence of refractive index – $n_v$, $n_r$ and $n_b$; angle of dispersion; dispersive power; constringence or Abbe number. Deviation without dispersion – achromatic prisms; dispersion without deviation; thin prism – ophthalmic prisms; definition of prism diopter.
8. Plane mirrors; sign convention; effect of rotation of a mirror; height of a mirror and VA charts. Spherical mirrors; image formation by convex and concave mirrors; ray tracing; lateral magnification in convex and concave mirrors; applications of mirrors – ophthalmic and otherwise.
9. Imaging by a system of two or more lenses using step along vergence; front and back vertex powers; nominal equivalent power. Calculation of the positions of the cardinal points.

Geometric Optics-II

1. Review of Geometric Optics I: refractive index; plane and spherical waves; vergence; rays; sign convention; laws of reflection and refraction; prisms; power of a spherical surface; thin lenses; effectivity; thick lenses; cardinal planes.
2. System of two or more thin lenses. Gullstrand's schematic eye model: power of the cornea, the lens and the eye; axial length; calculation of the position of the cardinal points; magnification.
3. Refraction by a cylindrical surface; astigmatism; line focus. Combination of two cylindrical surfaces. Spherocylindrical lenses, meridians of maximum and minimum powers; interval of Sturm; circle of least confusion. Jackson's crossed cylinder. Representations of spherocylindrical lenses and conversions between them.
4. Introduction to refractive errors – myopia and hyperopia; corneal curvature; axial length; far point; corrections; astigmatism; blur size; circle of least confusion; correction.
5. Object closer than at infinity; introduction to accommodation; near point; presbyopia. Spectacle and contact lens corrections; conjugacy of magnifications. Aphakia and pseudophakia; imaging in eye without lens; IOLs; magnification.
6. Chromatic aberrations; constringence (Abbe number); achromatic doublet.
7. Introduction to monochromatic ray aberrations; relation to wavefront aberration. Seidel aberrations in detail. Methods of reducing spherical aberrations; coma; distortion. Ocular aberrations – spherical aberrations and coma; chromatic aberrations.
8. Microscopes and hand-held magnifier; lensometer.
9. Telescopes.
10. Stops (entrance and exit pupils).
11. Defocus blur; depth of focus; depth of field; f-number.

***Appendix A.*** *Click to enlarge*

# Blebitis: a Teaching Case Report

Jeffrey Ho, OD, FAAO, and Joseph Gallagher, OD, FAAO | Optometric Education: Volume 45, Number 2 (Winter-Spring 2020)

PDF of Article

**Background**

The following case report explores the presentation, diagnosis and treatment of a bleb-related infection. The case may benefit third- and fourth-year optometry students as well as optometry residents in managing a complex eye condition in the setting of multiple ocular and systemic comorbidities. Understanding the management of blebitis and bleb-related infections is important for optometry students and residents. This condition may appear in their future practice, and prompt treatment will benefit patients.

**Case Description**

An 83-year-old white male presented to the clinic with complaint of mild irritation and foreign body sensation of the right eye for two days duration. The patient recalled getting topical fluorouracil cream for his skin cancer into his right eye before the symptoms began. The eye had become red with sticky discharge the day after the onset of irritation, which was confirmed by the accompanying nurse from his assisted-living residence. The patient denied eye pain or changes in his vision. He did note a brow ache above the eye, and the eyelids of the right eye had been stuck together upon awakening for the past two mornings.

The patient's medical history was remarkable for actinic keratosis on the right facial region, hypertension, transient cerebral ischemia, peripheral neuropathy, benign prostate hyperplasia, abdominal aortic arch repair and a previous myocardial infarction. He had no known medication allergies, but he did have known adverse drug reactions to lisinopril and pseudoephedrine. Active medications for the patient included amlodipine besylate, ammonium lactate lotion, aspirin, atorvastatin, azathioprine, digoxin, duloxetine, finasteride, fluorouracil 5% cream, metoprolol, tamsulosin and warfarin. The patient's past ocular history was remarkable for primary open angle glaucoma and past trabeculectomy surgeries in both eyes of unknown date. He had severe visual impairment and glaucomatous visual field loss consistent with the Social Security Administration definition of legal blindness. The patient noted that his topical glaucoma eye drops (latanoprost at bedtime OS and dorzolamide twice a day OS) had been instilled into his left eye by his assisted-living residence staff every day, with good compliance.

The patient's entering distance visual acuity with correction was 8/180 OD on Feinbloom chart and 20/70 OS on Snellen chart. Pinhole acuity was not an improvement in either eye. Extraocular muscles demonstrated a full range of motion, without diplopia or pain in either eye. Pupils were equal, round and reactive to light OU; no afferent pupillary defect (APD) was present. Anterior segment evaluation by slit lamp biomicroscopy revealed matted eyelashes and thick mucopurulent discharge OD; clear OS. The bulbar conjunctiva had 3+ diffuse injection and a white, elevated bleb on the superior-temporal area OD. There was an elevated and quiet bleb on the superior-temporal area of the conjunctiva OS. The corneas of both eyes showed a mild amount of fine, superficial punctate staining. Anterior chamber evaluation showed 2+ cells without flare OD; no cells or flare OS. Anterior chamber angle estimation was open OU by Van Herick technique. The irides had bilateral superior-temporal peripheral iridectomies consistent with the history of prior bilateral trabeculectomies, but were otherwise unremarkable without synechiae, nodules or neovascularization OU.

Two cotton tipped applicators of a Transystem Sterile Transport Swab (Copan Diagnostics Inc.) were utilized to swab the nasal and temporal cul-de-sac debris and tears OD in order to run a culture for antimicrobial susceptibility and resistance detection. One drop of sodium fluorescein dye (Ful-Glo, Akorn Inc.) was instilled onto the superior bulbar conjunctiva of both eyes. There was no Seidel sign on the corneas nor the blebs OU. One drop of Fluorescein Sodium and Benoxinate Hydrochloride Ophthalmic Solution USP, 0.25%/0.4% (Bausch & Lomb Inc.) was then instilled into both eyes. Intraocular pressures (IOPs) measured by Goldmann applanation tonometry were 3 mmHg OD and 9 mmHg OS, which were slightly lower than his typical reading in both eyes. The patient's right pupil was dilated with one drop of 1% tropicamide, one drop of 2.5% phenylephrine and one drop of 1% atropine. The patient deferred dilation of the left eye, which did not have signs or symptoms of inflammation. Internal eye examination of the right eye was performed utilizing a slit lamp with a 78D lens and binocular indirect ophthalmoscopy with a 20D lens. The posterior segment revealed a clear and centered posterior-chamber intraocular lens. The vitreous cavity had a complete posterior vitreous detachment with Weiss ring. Posterior segment evaluation revealed a cup-to-disc ratio of 0.95H/0.99V with minimal nasal rim remaining, mild pigment mottling at the macula without edema, and mild attenuation and tortuosity of blood vessels. The mid-peripheral and peripheral retina was flat and intact. There were no

signs of retinopathy or posterior inflammation OD.

Based on the clinical presentation, a diagnosis of blebitis was considered most likely, and the patient was prescribed moxifloxacin hydrochloride ophthalmic 0.5% solution (Vigamox, Alcon Laboratories Inc.) every hour OD. A loading dose of the medication was instilled into his right eye every 15 minutes for one hour in-office. A combination ointment of Neomycin and Polymyxin B Sulfates and Bacitracin Zinc Ophthalmic Ointment USP (Bausch & Lomb Inc.) was prescribed to be used in the right eye at bedtime. The patient was instructed to instill Vigamox into the right eye if he woke up during the night. The patient was also instructed to continue his current topical glaucoma medications (latanoprost at bedtime OS and dorzolamide twice a day OS), as previously prescribed. All instructions for medications were written for the patient and accompanying caretaker to deliver to the care team in his assisted-living residence. The patient was scheduled for a one-day follow-up appointment. He was counseled on the condition, the importance of medication compliance and the need for follow-up visits. The purpose of the prescribed medications and the purpose of long-acting iris dilatation with atropine were explained. The Transystem Sterile Transport Swab was hand-delivered to the hospital's laboratory for bacterial susceptibility and culturing.

*Follow-up visit #1*

The patient presented the next day to follow up on his anterior segment condition. He reported that his eye felt slightly less achy and his vision remained unchanged. He noted that the caretakers at his assisted-living residence instilled Vigamox every hour into his right eye the day before, but they stopped the eye drops the day of the follow-up appointment. The caretakers also instilled the antibiotic ointment in the right eye at bedtime the prior night. The patient's distance visual acuity with correction was 5/300 OD on Feinbloom chart and 20/100+ OS on Snellen chart. The pupil OD was pharmacologically dilated, and the pupil OS was normal and reactive to light. No APD was noted by inverse testing. Anterior segment evaluation with slit lamp biomicroscopy revealed matted eyelashes and less discharge OD than at the initial presentation. The bulbar conjunctival injection was less diffuse and mainly localized around the white, avascular, elevated bleb OD. The cornea was clear. There was no Seidel sign on the corneas nor the blebs OU. Anterior chamber evaluation still showed a moderate 2+ cells without flare OD. All anterior segment findings OS were unchanged. One drop of sodium fluorescein/benoxinate solution was instilled into both eyes. IOPs measured by Goldmann applanation tonometry were 4 mmHg OD and 12 mmHg OS. Internal eye examination by slit lamp, funduscopy and binocular indirect ophthalmoscopy revealed unchanged findings OD compared to the prior visit.

The patient was given written instructions to deliver to his caretakers regarding the importance of compliance with the eye drops as well as changes with directions to the medications. Instructions were given to the patient verbally and in writing to continue Vigamox every hour in the right eye and the neomycin combination ointment at bedtime in the right eye. Atropine 1% was added to the regimen to be used once a day OD only. The addition of a topical steroid was considered at the visit, but deferred until infection signs improved. The patient was instructed and scheduled to return one day later.

*Follow-up visit #2*

The patient presented the next day and reported that his right eye was less red and felt much better and he was experiencing less photosensitivity. Medications were reviewed with the patient, and all medications were being instilled as directed with good compliance. The patient's distance visual acuity with correction was 5/300 OD on Feinbloom chart and 20/80- OS on Snellen chart. The pupil OD was pharmacologically dilated, and the pupil OS was normal and reactive to light. Anterior segment evaluation by slit lamp biomicroscopy revealed mildly matted eyelashes and no discharge OD. The bulbar conjunctiva had mild injection only around the bleb OD. Anterior chamber evaluation showed a mild 1+ cell reaction OD. All anterior segment findings OS were unchanged. One drop of sodium fluorescein/benoxinate solution was instilled into both eyes. IOPs measured by Goldmann applanation tonometry were 3 mmHg OD and 14 mmHg OS.

The blebitis appeared to be resolving well. Vigamox was decreased to four times a day OD, neomycin combination ointment was increased to twice a day OD, and atropine 1% was continued once a day OD. The patient was instructed and given written instructions regarding the changes to his topical medications. The addition of a topical steroid was once again considered at this visit but deferred until the final bacteria culture report was available. The patient was instructed to call the eye clinic's 24-hour on-call service if symptoms worsened over the weekend. He was scheduled for a follow-up visit in three days.

*Follow-up visit #3*

The patient presented three days later, on the following Monday. He reported that his eye was much less red and no longer painful, but he felt dryness with occasional foreign body sensation OD. He reported good compliance with all medications. The patient's distance visual acuity with correction was 8/400 OD on Feinbloom chart and 20/70 OS on Snellen chart. The pupil OD was pharmacologically dilated, and the pupil OS was normal and reactive to light. Anterior segment evaluation by slit lamp biomicroscopy revealed mild dry debris along the eyelashes OD. The bulbar conjunctiva had trace injection around the white, elevated bleb OD. Anterior chamber evaluation showed trace cell reaction OD. The cornea showed mild diffuse superficial

punctate staining, greatest on the inferior and nasal epithelium OD. One drop of sodium fluorescein/benoxinate solution was instilled into both eyes. IOPs measured by Goldmann applanation tonometry were 7 mmHg OD and 12 mmHg OS.

The lab culture report from the swab taken at the initial exam was positive for *Pseudomonas aeruginosa*. The anterior chamber reaction and blebitis appeared to be nearly resolved. There was mild medicamentosa at the visit. The patient was verbally instructed and given written instructions to stop both the neomycin combination ointment and the atropine. He was instructed to continue Vigamox four times a day OD for seven days, then stop. Preservative-free Refresh Plus carboxymethylcellulose artificial tears 0.5% (Allergan Inc.) were prescribed to be used four times a day or more OU. Once again, the patient was instructed to call the eye clinic's 24-hour telephone triage service if symptoms worsened. He was scheduled for a two-week follow up.

*Follow-up visit #4*

Two weeks later the patient presented for follow-up and reported complete resolution of his symptoms. However, he was still using Vigamox four times a day OD. The patient's distance visual acuity with correction was 8/220 OD on Feinbloom chart and 20/70 OS on Snellen chart. Pupils were equal, round and reactive to light OU; no APD was present. Anterior segment evaluation by slit lamp biomicroscopy revealed mild dry debris along the eyelashes OU. The bulbar conjunctiva had an elevated, clear, avascular bleb OD and was otherwise unremarkable. Anterior chamber evaluation showed no cells OD. The cornea showed no staining OD. One drop of sodium fluorescein/benoxinate solution was instilled into both eyes. IOPs measured by Goldmann applanation tonometry were 6 mmHg OD and 12 mmHg OS.

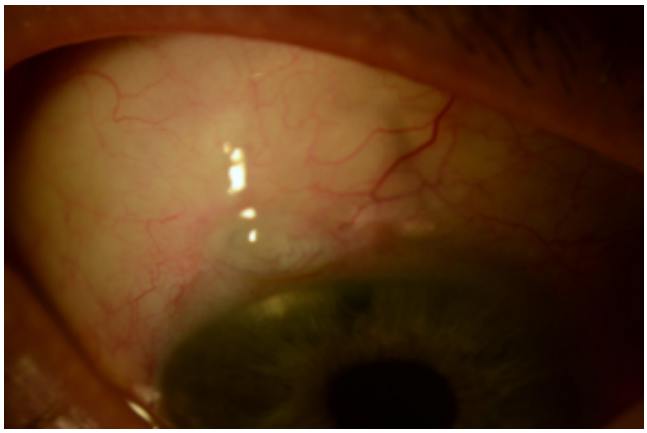

***Figure 1.*** *Healthy drainage bleb in the right eye following successful treatment of infection.*
*Click to enlarge*

**TABLE 1**
**Summary of Office Visits**

| Visit | Visual Acuity | Anterior Chamber Reaction | Intraocular Pressure | Related Symptoms | Treatment |
|---|---|---|---|---|---|
| **Initial visit** | OD: 8/160<br>OS: 20/70 | OD: 2+ cells | OD: 3 mmHg<br>OS: 9 mmHg | OD: brow ache, mucopurulent discharge, 3+ injection, trace corneal staining | Vigamox Q1H OD<br>Neosporin QHS OD<br>Atropine in-office OD |
| **Follow-up #1 (1-day)** | OD: 5/300<br>OS: 20/100+ | OD: 2+ cells | OD: 4 mmHg<br>OS: 12 mmHg | OD: mild brow ache, less discharge, 2+ injection | Vigamox Q1H OD<br>Neosporin QHS OD<br>Atropine Q1D OD |
| **Follow-up #2 (1-day)** | OD: 5/300<br>OS: 20/60- | OD: 1+ cells | OD: 3 mmHg<br>OS: 14 mmHg | OD: no pain, 1+ injection | Vigamox QID OD<br>Neosporin BID OD<br>Atropine Q1D OD |
| **Follow-up #3 (3-day)** | OD: 8/400<br>OS: 20/70 | OD: trace cells | OD: 7 mmHg<br>OS: 12 mmHg | OD: trace injection, 1+ diffuse corneal staining | Vigamox QID OD x 7 days, Preservative-free Refresh Plus QID OD |
| **Follow-up #4 (2 wks)** | OD: 8/220<br>OS: 20/70 | OD: no cells | OD: 6 mmHg<br>OS: 12 mmHg | N/A | Refresh Plus as needed |

***Table 1.*** *Click to enlarge*

The blebitis and anterior chamber reaction were completely resolved at this visit **(Figure 1)**. The patient was counseled and given written instructions to discontinue use of Vigamox. Refresh Plus eye drops were to be continued as needed for dryness OU. Glaucoma medications were to be continued OS as directed. The patient was reminded to call the eye clinic's 24-hour telephone triage service if symptoms recurred. He was scheduled for a two-month follow-up appointment to continue glaucoma testing. **Table 1** provides a summary of the patient encounters.

**Education Guidelines**

*Key concepts*

- Recognition of the clinical manifestations of blebitis
- Treatment options and management of blebitis
- Differential diagnoses when encountering bleb-related infections

*Learning objectives*

At the conclusion of this case report, readers should be able to:

- Describe the signs and symptoms of blebitis
- Understand the risk factors for blebitis and bleb-related infections

- Outline a variety of differential diagnoses for blebitis
- Describe the treatment and management plan for this condition
- Appreciate different classes of antibiotic agents as well as the risk for resistance

*Discussion questions*

- How does blebitis differ from other red eye presentations?
- How can blebitis and endophthalmitis present similarly?
- Describe the ocular presentation of blebitis
- What are the symptoms of blebitis?
- Describe risk factors related to bleb-related infections
- Discuss treatment options for bleb-related infections
- When should intravitreal antibiotic injections be considered?
- What is the visual prognosis for blebitis?

*Learning assessment*

- Knowledge of the condition can be strengthened by comparing differential diagnoses in small-group environments
- Reviewing images of healthy blebs to images of bleb-related infections can improve student recognition of abnormal findings
- Case discussion in an integrative seminar can combine knowledge from the clinical and didactic points of the case in a comfortable, open environment
- Presenting interactive quizzes on PowerPoint slides can reveal concepts from the case for which students may need additional review

**Discussion**

Bleb-related infections are an emergent and potentially visually devastating complication of glaucoma filtering surgeries. They can occur at any time post-surgery and may not affect patients' vision during the course of infection.[1-3] IOP is typically in hypotony ranges less than 5 mmHg.[4,5] Brown et al.[6] first used the term "blebitis" in 1994 to describe an isolated bleb infection without vitreous involvement.[6] It is crucial for a clinician to develop a strong clinical acumen in diagnosing and managing this infection to control its course. Understanding risk factors for blebitis and differentials of the condition as well as employing an evidence-based management approach will help the astute clinician provide prudent care for the patient.

*Presentation and symptoms*

Patients usually present with a red, painful eye in both blebitis and bleb-associated endophthalmitis, but the signs and symptoms of endophthalmitis tend to progress more rapidly and the disease course is more visually devastating.[1,6-10] Blebitis may represent the initial state in a continuum of infection to early endophthalmitis.[6-9] Patients with blebitis present with a variety of symptoms including redness, irritation, photophobia, purulent discharge, intense peri-bleb conjunctival congestion, opalescent bleb, fluorescein staining defects and mild to moderate anterior segment inflammation.[1,6,8-10] Patients with bleb-associated endophthalmitis present with similar infectious signs and symptoms that rapidly worsen, including anterior chamber hypopyon and vitritis.[6,8-10] Occasionally, prodromal signs and/or symptoms, such as brow ache, headache or external eye infection or inflammation, may be present days to weeks before the diagnosis of bleb-related infection.[4]

*Incidence*

The cumulative incidence rate of bleb-related infections varies across different cohorts, uniformity of surgical technique and different periods of follow-up.[11] Based on the Collaborative Initial Glaucoma Treatment Study, the five-year risk of blebitis and hypotony were both 1.5%, and the risk of endophthalmitis was 1.1%.[3] A retrospective cross-sectional study utilizing a commercial health insurance claim-based database at Bascom Palmer Eye Institute found that the five-year incidence rate of blebitis in the United States was 0.55% with an average onset time of 45 months after the filtration procedure.[12] The five-year incidence rate of bleb-associated endophthalmitis was 0.45% to 1.3% with an average onset time of 33 months after procedure.[12] A large retrospective case-controlled observational study utilizing 22 years of analyzed data at St. Erik's Eye Hospital in Sweden found a 0.46% combined incidence of all bleb-related infections with a median onset time of 10 days for early infections and four years for late infections.[2] Long-term follow-up studies have shown the incidence of cumulative bleb-related infections to be less than 2% at the 10-year mark.[13]

*Risk factors*

Risk factors for bleb-related infections include diagnosis of juvenile glaucoma or pigmentary glaucoma, black race, presence of

blepharitis, presence of punctal plugs, young age at time of surgery, inferior-placed trabeculectomy, use of perioperative antimetabolites, history of or current bleb leak, bleb manipulation and sustained low IOP or hypotony.[2,4,5,10-15] The patient in this case had a self-reported history of prior trabeculectomies, but the surgical date was unknown. Younger age at time of filtration surgery can increase the risk for blebitis, with a 1.08 conditional risk for every five years of decreasing age.[14] A retrospective chart review by Sharan et al. found that individuals with bleb-related infections had a mean age at surgery of 53.5 years compared with 64.7 years for those without infection.[15]

*Antimetabolite agents*

The use of antimetabolite agents mitomycin C (MMC) and 5-fluorouracil (5-FU) are known to increase filtration surgery success rates and likely lead to improved IOP reduction.[2,11-15] However, their application leads to a thin and avascular bleb, which may increase the risk for pathogens to migrate across the bleb.[2,10-14] MMC has been shown to have a higher potential to increase the risk of bleb-related infections than 5-FU.[2,10,11,13,14] A study by Wallin et al.[2] found that the incidence of late infections was 0.7% when MMC was utilized compared to 0% incidence when no antimetabolite was used.[2] This risk is higher in hypotonous eyes.[11] Risk of bleb-related infections is also increased in patients with fully functioning blebs that no longer required topical glaucoma medications for IOP control.[13]

The patient in this case report was applying fluorouracil 5% cream to the right side of his face for the management of actinic keratosis for the two weeks before eye symptoms began. The exact amount and frequency the cream was in contact with the eye was not known. The cream may have had the potential to affect the bleb, though this was less likely a risk because the patient was well outside the perioperative window where fluorouracil may have had a larger impact.

*Bleb leaks*

Bleb leaks can occur any time after trabeculectomy. The risk for infection is higher in late bleb leaks compared with early bleb leaks.[4,13,14] However, a leak in the bleb at any time puts patients at risk for infection.[4,10,13-15] Poulsen et al.[4] found that patients with a bleb leak were 25.8 times more likely to have a bleb-related infection than those without a bleb leak.[4] The bleb leak may also be responsible for significant hypotony at infection onset.[4] Seidel testing may be negative, even in cases where bleb trauma precedes infection, because the leak site may be plugged by mucopurulent debris.[8,9] In this case report, Seidel testing was negative on the bleb and the cornea of the patient. Discharge and/or aqueous fluid was not seen leaking from either tissue, which was an initial indication that surgical intervention was not necessary at the time. When blebs leak, surgical revision can be favorable and decrease risks of bleb-related infections.[13]

Inferior-placed trabeculectomies are a major risk factor for infection.[2,5,10,11] Inferior-located blebs are poorly covered by the lower eyelid and are more exposed to bacterial flora on the ocular surface.[5,11] The chronic mechanical abrasive movement of the lower eyelid can create a leak on the bleb and migrate bacteria into the anterior chamber.[11]

*Microbial infection*

The main bacterial etiologies of bleb-related infections are *Staphylococci*, *Streptococci* and *Haemophili*.[2,8,10,11] The pathogens involved in bleb-related infections are typically isolated from the ocular surface and not from within the eye.[11] The gram-positive bacteria are consistent with the normal flora typically residing on the ocular surface tissues.[7,11,16] Infections caused by virulent *Streptococci* seem to result in worse visual prognosis than infections relating to other bacterial flora.[2,8,10,11] Broad-spectrum antibiotic coverage is therefore reasonable for empirical treatment.

*Antimicrobial treatment*

The patient in this case report had blebitis caused by *Pseudomonas aeruginosa*. Vigamox eyedrops and a combination antibiotic ophthalmic ointment of Neomycin and Polymyxin B Sulfates and Bacitracin Zinc USP were the medications chosen to provide broad-spectrum antibiotic coverage, before the culture report was available. The fluoroquinolone class of antibiotics provides excellent broad-spectrum antibiotic coverage.[17-19] The second-, third- and fourth-generation forms show similar antimicrobial efficacy against gram-negative bacteria, but the fourth-generation provides additional potency against gram-positive bacteria.[17,18] The newer third-generation levofloxacin ophthalmic solution 1.5% (Iquix, Vistakon Pharmaceuticals LLC) does not appear to be superior in potency to fourth-generation fluoroquinolones.[18] The reason the fourth-generation fluoroquinolones (moxifloxacin, gatifloxacin, and besifloxacin) are likely more potent and have less probability of bacterial resistance than fluoroquinolones of prior generations may be due to their unique capability of simultaneously inhibiting both deoxyribonucleic acid gyrase and topoisomerase IV enzymes in gram-positive bacteria.[17,19] Moreover, two spontaneous enzyme mutations would be necessary to generate resistance against fourth-generation antibiotics.[19,20]

Antimicrobial resistance can still develop in fourth-generation antibiotics, more frequently in gram-negative than gram-positive

microbes.[19] The fourth-generation synthetic fluoroquinolone besifloxacin ophthalmic suspension 0.6% (Besivance, Bausch & Lomb Inc.) is specifically for topical application only, which theoretically reduces antimicrobial resistance.[20] Besifloxacin shows similar, if not favorable and more rapid, bactericidal activity compared with similar-generation fluoroquinolones and is a suspension formulated with the polycarbophil-based vehicle DuraSite (InSite Vision, Inc).[20-22] DuraSite is mucoadhesive and exhibits thixotropy. This formulation allows for prolonged drug exposure on the ocular surface, improved ocular pharmacokinetics and increased stability of the medication during manufacturing and storage.[20-23] Based on the strong antimicrobial efficacy and low resistance rate, these forms of fluoroquinolones seem to be an appropriate starting point for broad-spectrum antibiotic coverage.

*Blebitis management*

The treatment and management of blebitis is highly variable between providers. A survey conducted in the United Kingdom (UK) found that treatment regimens included topical fluoroquinolone monotherapy, dual topical antibiotic therapy, oral fluoroquinolones, subconjunctival antibiotic injections and intravitreal antibiotic injections.[7] There was not a clear consensus on the treatment protocol, but topical cycloplegic agents were widely part of the management of all infections, with greater than 90% consensus.[7] An earlier survey conducted by the American Glaucoma Society (AGS) found that the three main treatment regimens were topical fluoroquinolone monotherapy (typically initial empirical treatment), topical fluoroquinolone in combination with fortified agents, and topical fluoroquinolone in combination with unfortified aminoglycoside or trimethoprim-polymyxin combination or equivalent.[9] Oral, intravenous and subconjunctival agents were not frequently utilized.[9] In both surveys, topical corticosteroids were often prescribed but typically only after antibiotic therapy was already initiated for more than 24 hours (UK survey) or after initial antibiotic treatment was established or improvement of blebitis was noted (AGS survey).[7,9]

Topical antibiotic therapy is widely used as initial empirical treatment for blebitis.[1,7,9] Systemic, intravenous and subconjunctival agents may be considered in cases with a moderate to severe anterior chamber reaction or signs of vitreous involvement.[1] Systemic antibiotics were utilized less frequently in the past due to the minimal vitreous bioavailability, but more recent antibiotics have shown improved ability to cross the blood-eye barrier.[24] Fourth-generation fluoroquinolones should be utilized for their increased vitreous bioavailability, lower bacterial resistance and broad-spectrum activity.[24] When endophthalmitis is suspected, vitreous tap with intravitreal antibiotic injection may be warranted.[1,24] Patients with severe cases of bleb-related endophthalmitis may benefit from additional 25-gauge vitrectomy to decrease the bacterial load.[24]

*Culture swab*

The decision for acquiring a conjunctival culture swab varies by individual provider and extent of infection.[7,9] The bacterial flora involved in bleb infection may not necessarily equate to the colonizing flora of a positive bleb culture.[7] Interestingly, the AGS survey showed that providers who routinely acquired conjunctival culture swabs had a similar empirical antibiotic regimen to providers who did not acquire cultures.[9] Conjunctival culture swab was elected for the patient described in this report. A topical fourth-generation fluoroquinolone was chosen as the primary antibiotic regimen in the case due to its broad-spectrum activity and relatively low resistance profile. If bacterial culture and susceptibility testing revealed a different microbe, the treatment regimen may not necessarily have changed, unless the report showed resistance to the selected fluoroquinolone.

*Visual prognosis*

The patient in this case report did not have a significant visual change during the course of the blebitis, though he already had low vision prior to the infection. Vision may not be affected at the onset or during the course of blebitis.[2,3,10] Visual prognosis after infection seems to be related to the degree of infection. Patients with blebitis treated promptly with intense antimicrobial agents tend to have favorable outcomes and recover visual acuity and IOP to pre-infection status.[2,4,10] Cases involving late and severe bleb-associated endophthalmitis unfortunately show poor visual prognosis (vision less than 20/200 to light perception) despite aggressive and prompt treatment.[2,4,6,10]

*Differential diagnosis*

- Anterior uveitis may present with a red, painful, watery eye.[25,26] Patients may experience photosensitivity, and a varying amount of cells and fibrin are seen in the anterior chamber. Vision may be reduced in some cases, depending on the turbidity of the aqueous.[25-27] The uveitis can be classified as granulomatous or non-granulomatous, depending on the nature of keratic precipitates present on the corneal endothelium.[27] IOP can be lower than the patient's normative value in the acute phase due to decreased aqueous production from ciliary body inflammation, or higher due to trabeculitis and cellular debris in the trabecular meshwork.[25]
- Herpes zoster keratouveitis may present with a unilateral red, irritated eye with tearing.[28] The patient may also experience

headache, fever and malaise.[28] The cornea of the involved eye may have raised pseudodendrite lesions or mucus plaques. Depending on the time course of the condition, painful ulcerating or scabbing vesicles may be seen on the face that follow the trigeminal dermatomes.[28] IOP may also be elevated from trabeculitis.[27-29]

- HSV endotheliitis may present with a mildly red eye, photosensitivity, eye pain and variable decreased vision.[30] The corneal stroma is edematous, and a mild anterior chamber reaction may be present.[31,32] IOP may be elevated in the involved eye due to trabeculitis.[27,29,30]
- Bacterial blepharoconjunctivitis presents with an erythematous, edematous, crusty, irritated eye involving the lids and conjunctiva.[33-35] Excess bacterial flora and exotoxins may cause saponification of tears, and superficial punctate keratitis may be present on the cornea.[33,35] The condition may be unilateral or bilateral, and occasionally an oily or purulent discharge may be present.[34,35]
- Medicamentosa keratoconjunctivitis may occur due to chemical eye trauma from exposure to eye drops, cosmetics, environmental irritants, or in the case of the reported patient, topical skin creams and ointments that spread into the eye. The patient may experience vision changes, foreign body sensation, redness, lacrimation, ocular pain and blepharospasm.[36,37] The eye may show signs of superficial punctate keratitis, corneal edema, conjunctival hyperemia, erythema and blistering of the lids and adnexa.[36-38] In severe cases with alkali penetration through the cornea, an anterior chamber reaction may be present and IOP may be elevated.[36]

**Conclusion**

This case reviews the presentation and management of blebitis. The patient presented in the case did not experience significant visual changes during the course of the infection, though he had pre-existing poor vision at the date of diagnosis. Perioperative antimetabolite application is a known risk factor for bleb-related infections. The patient in this case did have ocular exposure to fluorouracil cream, though the causative value is questionable. There is not an absolute guideline on the treatment of bleb-related infections, but aggressive treatment with antimicrobial agents tends to have favorable outcomes. Patients should be followed routinely during the course of treatment, and any worsening signs should indicate more aggressive treatment and further workup for endophthalmitis. With prompt and prudent treatment, blebitis typically resolves and vision has the potential to return to pre-infection status.

**Disclosure**

The authors do not have any financial or intellectual conflicts of interest regarding devices, medications or products mentioned in this manuscript.

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# Management of Acute Corneal Hydrops in a Patient with Keratoconus: a Teaching Case Report

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PDF of Article

**Background**

Keratoconus is typically thought to be a bilateral disease that can present asymmetrically. It is associated with progressive corneal ectasia and scarring. With no definitive etiology, the corneal ectasia ultimately leads to irregular astigmatism, central anterior scarring and reduced vision.[1] Hydrops is a rare condition experienced by some keratoconic patients. Hydrops is characterized as a break in Descemet's membrane and underlying endothelium. This allows aqueous humor to leak into the stroma and cause stromal edema.[2]

**Student Discussion Guide**

A 49-year-old Indian male presented for examination in a primary eyecare clinic with complaints of light sensitivity, mild ocular redness and a visible white spot in the left eye.

The History of Present Illness included a burning sensation OS with "foggy" vision, but the patient denied any discharge. The patient reported that the burning sensation started approximately one week prior to his visit. He had been self-medicating with Systane Lubricant Eye Drops (Alcon) three times a day in both eyes and Zaditor (ketotifen fumarate, Novartis) twice a day in both eyes, with mild relief. He denied any similar incidences in the past. He had no complaints at the time of his last vision and ocular health examination, which was nine days earlier with a different provider in the same clinic. At that visit, his best-corrected visual acuity was 20/20 OD and 20/60-2 OS (pinhole: no improvement).

The patient's Past Ocular History included keratoconus (oval cone in both eyes, OS larger than OD) with long-standing scarring of the left eye, dry eye syndrome, chronic allergic conjunctivitis and presbyopia. He was unsure when he was diagnosed with keratoconus but recalled his vision becoming poor in his early 20s. Piggyback contact lenses were self-discontinued approximately two years prior due to poor comfort. The patient denied any past ocular surgery or ocular trauma. His Past Medical History was unremarkable, with no use of systemic medications. His Family History was significant only for keratoconus (brother). His Social History was negative for tobacco, alcohol or recreational drug use. He had no known allergies or drug allergies. He was oriented to time, place and person, and his mood was appropriate.

*Examination findings*

Entrance visual acuity (with spectacles):

OD: 20/20

OS: 20/400 (pinhole: no improvement)

Manifest subjective refraction:

OD: +1.75 -4.50 x 055  20/20

OS: +0.75 -4.50 x 120  20/400  ADD: +1.50 20/20 OU at 40 cm

Pupils were equal, round and reactive to light (with no afferent pupillary defect). Confrontation visual fields were full to static fingers in both eyes. Extraocular muscle motility was full in all gazes.

Slit lamp biomicroscopy:

Lids/lashes: few capped meibomian glands OU

Palpebral conjunctiva: trace papillae OU

Bulbar conjunctiva: trace injection OU

Tears: thin lacrimal lake OU

Cornea:

OD: moderate inferior thinning with no scarring; Fleischer's ring and striae present

OS: moderate inferior thinning; 6-mm area of dense and diffuse stromal edema with an underlying break in Descemet's membrane slightly below the visual axis

Iris: flat OU

Lens: clear OU

Anterior chamber: grade IV angle and free of visible aqueous cells or flare OU

Goldmann applanation tonometry:

OD: 11 mmHg

OS: 11 mmHg (with irregular mires)

@ 10:30 a.m.

The appearance of the cornea in the left eye and timing suggested a diagnosis of corneal hydrops. A 6-mm area of stromal edema with an underlying break in Descemet's membrane was present. There were no obvious epithelial defects. Subjective complaints of blurry vision and a burning sensation were reported. No anterior chamber reaction or discharge were seen. The patient was started on Muro 128 ophthalmic solution (sodium chloride hypertonic solution 5%, Bausch + Lomb) three times a day along with Muro 128 ointment (sodium chloride hypertonic ointment 5%, Bausch + Lomb) at bedtime. He was also educated to continue using artificial tears three times a day in both eyes. Follow-up was scheduled for five days in an anterior segment specialty unit.

*Follow-up visit #1*

The patient returned as scheduled for his follow up. He reported good compliance with the prescribed treatment regimen, but no change in his symptoms. The patient's spectacle-corrected distance visual acuity remained stable at 20/20 OD and 20/400 OS (pinhole: no improvement). Slit lamp biomicroscopy revealed no changes in the right eye. Evaluation of the left cornea showed a 5-mm area of dense and diffuse stromal edema with an underlying break in Descemet's membrane slightly below the visual axis. There were no evident epithelial defects. Intraocular pressure (IOP) measured with Goldmann applanation tonometry at 2:15 p.m. was 12 mmHg OD and OS (with irregular mires OS). The diagnosis of corneal hydrops was confirmed.

The patient was instructed to continue using Muro 128 ophthalmic solution 5% three times a day and Muro 128 ointment at bedtime in the left eye. The patient was extensively educated on his condition and possible long recovery time (average of three months). The option of a surgical consult vs. the topical medications was discussed. The patient elected to continue the topical/medical therapy, and a follow-up appointment was scheduled for one month.

*Follow-up visit #2*

The patient returned as scheduled for his follow-up appointment. He reported that the burning sensation had subsided, but that he occasionally felt his left eyelid "hitting something on the eye." He reported a new symptom of glare in bright sunlight. He had been using Muro 128 ophthalmic solution 5% three times a day and Muro 128 ointment at bedtime as instructed. The patient also reported that he felt a "gritty sensation" when waking up in the morning several days prior to this visit. His spectacle-corrected visual acuity was 20/20 OD and 20/400 OS (pinhole: 20/200 OS). Slit lamp biomicroscopy evaluation of the left cornea showed a 3-mm area of diffuse stromal edema with an underlying break in Descemet's membrane slightly below the visual axis. There were no evident epithelial defects. IOP measured at 1:30 p.m. with Goldmann applanation tonometry was 12 mmHg OD and OS (with irregular mires OS).

Because the patient reported having an ocular gritty sensation in the mornings, he was told to discontinue Muro 128 ointment and to use Soothe Lubricant Eye Ointment (Bausch + Lomb) instead. To help with the glare sensitivity he reported, he was started on Lotemax Gel 0.5% (loteprednol etabonate, Bausch + Lomb) four times a day in the left eye and advised to wear full-

rimmed sunglasses when outdoors to block more sunlight. A follow-up visit was scheduled for one month.

*Follow-up visit #3*

The patient returned as scheduled for his follow-up visit. He reported having persistent glare but obtaining prescription sunglasses, which helped. He reported that he discontinued Lotemax because he experienced mild sensitivity after using it. He said he was using the Soothe ointment two to three times per day and at night. His spectacle-corrected distance visual acuity was 20/20 OD and 20/200 OS (pinhole: 20/100 OS). Slit lamp evaluation of the left eye revealed a 3-mm area of mild corneal stromal edema with early scarring below the visual axis. No break in Descemet's membrane was visible, and no sodium fluorescein staining was seen. IOP measured at 2:15 p.m. with Goldmann applanation tonometry was 13 mmHg OD and OS (with irregular mires OS).

The patient was instructed to discontinue Lotemax Gel 0.5%, and to use only Soothe Lubricant Eye Ointment in the left eye throughout the day and at night. A follow-up appointment was scheduled for one month. The patient was informed that at the next visit, scleral contact lenses would be used to determine his best-corrected visual acuity.

*Follow-up visit #4*

The patient returned as scheduled for his follow-up visit. He reported improvement in symptoms and that he had been using the Soothe ointment only as needed. His spectacle-correct distance visual acuity was 20/20 OD and 20/200 OS (pinhole: no improvement). Slit lamp biomicroscopy revealed no changes in the right eye. A 3-mm area of stromal scarring below the visual axis was present in the cornea of the left eye. There were no signs of sodium fluorescein staining. IOP measured with Goldmann applanation tonometry at 1:00 p.m. was 13 mmHg OD and OS (with irregular mires OS). An undilated 90D fundus examination revealed normal posterior segments (to the extent seen) that were noncontributory to this case. The cup-to-disc ratio was 0.45 vertically in each eye; the artery-to-vein ratio was 2:3 in each eye; and both maculas were clear with a positive foveal reflex in each eye.

**TABLE 1**
**Scleral Contact Lens Parameters**

| | Right Eye | Left Eye |
|---|---|---|
| Diameter | 15.6 mm | 15.6 mm |
| Sagittal Depth | 4,540 microns | 4,690 microns |
| Base Curve | 43.00 D | 47.00 D |
| Power | -2.00 D | -6.00 D |
| Fitting | central clearance: 250 microns, limbal clearance 360 degrees, and adequate edge alignment | central clearance: 250 microns, limbal clearance 360 degrees, and adequate edge alignment |
| Vision | -2.00 over-refraction, VA: 20/20 | -1.00 over-refraction, VA: 20/30 |

***Table 1.*** *Prescription for Custom Stable scleral contact lenses (Valley Contax) to determine the patient's best-corrected visual acuity.* Click to enlarge

Custom Stable scleral contact lenses (Valley Contax) were fitted for both eyes to determine whether vision could be improved. Lens parameters and resulting vision are noted in **Table 1**. Despite the improved visual acuity provided by the scleral contact lenses in each eye, the patient declined to complete the fitting process due to the cost. In the meantime, he was educated about continuing to use artificial tears and ointment as needed. A follow-up appointment, to include a dilated fundus exam, was scheduled for four to six weeks.

The patient did not return for the scheduled follow-up visit but did return for a comprehensive examination a year later in the primary eyecare clinic. At that time he had no complaints and reported he was happy in his glasses and his vision in the left eye had improved over time.

*Examination findings*

Visual acuity (with spectacles):

OD: 20/20

OS: $20/50^{-2}$ (pinhole: no improvement)

Manifest subjective refraction:

OD: +2.00 -4.50 x 055 20/20

OS: +0.75 -4.50 x 120 $20/50^{+1}$ ADD: +2.00 20/20 OU at 40 cm

Pupils were equal, round and reactive to light (with no afferent pupillary defect). Confrontation visual fields were full to static fingers in both eyes. Extraocular muscle motility was full in all gazes.

Slit lamp biomicroscopy:

Lids/lashes: few capped meibomian glands OU

Palpebral conjunctiva: trace papillae OU

Bulbar conjunctiva: trace injection OU

Tears: thin lacrimal lake OU

Cornea:

OD: moderate inferior thinning with no scarring; Fleischer's ring and striae present

OS: moderate inferior thinning; Fleischer's ring present; 4-mm area of stromal and endothelial scarring slightly below the visual axis

Iris: flat OU

Lens: grade 1 nuclear sclerosis OU

Anterior chamber: grade IV angle and free of visible aqueous cells or flare OU

Vitreous: syneresis OU

Goldmann applanation tonometry:

OD: 11 mmHg

OS: 11 mmHg (with irregular mires)

@10:30 a.m.

A dilated fundus examination revealed normal posterior segments (to the extent seen) that were noncontributory to this case. The cup-to-disc ratio was 0.45 vertically in each eye; the artery-to-vein ratio was 2:3 in each eye; the maculas were clear with a positive foveal reflex in each eye; and the retina was flat and intact with no breaks, tears or detachments in each eye.

Despite previous improvement in visual acuity with scleral contact lenses, the patient declined a new fitting due to having subjectively adequate vision with his current glasses. He was educated to continue utilizing artificial tears and ointment as needed, and a return visit was scheduled for one year.

**Educational Guidelines**

This teaching case report can serve optometry students who have completed, or are completing, an anterior segment/ocular disease course and a specialty contact lens course, as well as optometrists in clinical practice.

*Key concepts*

1. The pathophysiology of corneal hydrops and its impact on the cornea and keratoconus
2. Critical thinking in the diagnosis, treatment and management of corneal hydrops
3. Ensuring that patients understand all treatment options and the anticipated time to resolution, and have realistic expectations after resolution
4. The use of specialty contact lenses following corneal hydrops

*Learning objectives*

1. At the conclusion of this case discussion, participants should be able to:
2. Understand corneal hydrops from an anatomical standpoint
3. Differentiate corneal hydrops from other corneal conditions
4. Understand the typical patient demographic for corneal hydrops
5. Understand the risk factors in association with the clinical presentation to best manage the patient, including if/when referral is appropriate
6. Provide patient education regarding all management options and expectations for those options

*Discussion questions*

1. Knowledge and concepts required for critical review of the case:

    a. What are the typical clinical characteristics of corneal hydrops?

    b. How can one distinguish corneal hydrops from other corneal conditions?

    c. What would be the most appropriate management given the case provided?

2. Differential diagnosis:

    a. What differential diagnoses make the most sense given the clinical characteristics?

    b. What other factors need to be considered in this case?

    c. Are there any ancillary tests that would have been helpful in this diagnosis?

3. Disease management:

    a. How would you monitor this patient, if at all?

    b. What topical therapy would you prescribe, if at all?

    c. How would you determine whether you were going to manage this patient with conservative treatment only or refer for surgery?

    d. What timeline is most appropriate for this patient?

4. Patient education:

    a. How would you educate the patient regarding this diagnosis?

    b. What is the long-term prognosis for this patient?

    c. How would you discuss visual outcomes with conservative and surgical treatments?

5. Critical thinking:

    a. How would you have managed this case?

    b. Do you feel more prepared to manage or co-manage this condition?

*Assessment of learning objectives*

1. Case-based discussion of diagnosis and management of corneal hydrops
2. Clinical-thinking skills and knowledge of the clinical signs of corneal hydrops can be assessed in a small-group setting (e.g., seminar, Grand Rounds) and assessed as part of a written exam
3. Students should be evaluated on their knowledge of different corneal hydrops therapies and be able to create a treatment plan
4. Practical assessment of clinical tests that are commonly used in the diagnosis of corneal hydrops, e.g., anterior segment optical coherence tomography (OCT) and corneal topography
5. Written communications can be assessed by writing an information brochure for patients on corneal hydrops therapy
6. Literature review on evidenced-based corneal hydrops management could be written up as a dissertation

**Discussion**

Previously published data have shown that the estimated prevalence of keratoconus in the general population is 54 per 100,000.[1] A more recently published nationwide registration study in the Netherlands estimated the prevalence of keratoconus in the general population as 265 per 100,000.[22] Although the etiology of keratoconus is still not clear, it is believed that genetics, the environment (eye-rubbing, allergies) and the individual's endocrine system all play a role in the onset, progression and stabilization of the condition.[6]

The first case of corneal hydrops in the setting of keratoconus was reported by Plaut in 1900. It was described as a sudden opacity at the apex of the cornea due to a rupture of Descemet's membrane, which was later confirmed by Axenfeld in 1906.[2] Corneal hydrops occurs in 2.5-3.0% of the population with keratoconus. The majority of cases are unilateral, occur more frequently in males than in females, and typically present in the second or third decade of life.[2]

*Differential diagnosis*

The differential diagnoses for this patient included:

- Corneal ulcer, depending on size and location, involves different modalities of treatment. The usual presentation includes ocular redness, pain and light sensitivity. A hypopyon and/or anterior chamber reaction may also be seen. An epithelial defect with positive sodium fluorescein staining is observed. Depending on location, vision may or may not be affected.[3]
- Corneal hydrops patients may present with acute light sensitivity, pain (depending on patient's pain threshold), and a well-demarcated area of edema associated with a break in Descemet's membrane. An epithelial defect is not usually seen. Vision is decreased, but location determines how variable the visual acuity will be.[4]
- Corneal degenerations are changes in various layers of the cornea that tend to be unilateral, asymmetric and peripherally located. They are frequently associated with systemic conditions, and the changes that tend to occur include deposition, thinning and/or vascularization of the corneal tissue.[5]
- Corneal dystrophies are changes that usually occur in a single layer of the cornea. The changes tend to be bilateral and centrally located. They are usually not associated with systemic conditions but are inherited. Onset tends to be at a younger age compared to degenerations.[5]
- Corneal scarring may occur secondary to corneal trauma or infection.

In this case report, the appearance of the cornea in the left eye and timing suggested a diagnosis of corneal hydrops. A 6-mm area of stromal edema and an underlying break in Descemet's membrane were present. There were no obvious epithelial defects. Subjective complaints of blurry vision and a burning sensation were reported. No anterior chamber reaction or discharge was seen.

Acute corneal hydrops is characterized as a break in Descemet's membrane (and underlying endothelium) allowing aqueous humor to leak into the stroma and cause stromal edema. The breakage is spontaneous and most likely to occur in eyes with advanced thinning. Symptoms may include sudden onset decreased vision and irritation including pain and/or photophobia. Clinical signs include an observable break in Descemet's membrane, anterior and posterior stromal edema with possible epithelial involvement, and hyperemia of the conjunctiva.[4] The patient may also notice a visible "white spot" on their eye. Although usually associated with keratoconus, hydrops can also occur in other ectatic disorders such as pellucid marginal degeneration, keratoglobus and ectasia status post-LASIK, radial keratotomy or penetrating keratoplasty.[2] Complete resolution of signs and symptoms typically takes three to six months.

One of the proposed etiologies of keratoconus is eye-rubbing. There are several theories as to how rubbing causes keratoconus including increased concentrations of inflammatory mediators in the pre-corneal tears, large intraocular pressure spikes, a reduction in shear strength, and cone-forming deformation.[23] The corneal thinning along with some sort of corneal trauma (e.g., rubbing of the eyes) may be considered as an underlying cause of hydrops.[2,4] A 2013 study conducted in New Zealand showed that hydrops typically developed approximately four years after the diagnosis of keratoconus, and the subjects with hydrops were more likely to have a history of eye-rubbing (but less likely to have a family history of keratoconus). There was also no statistically significant differences in the prevalence of atopic disease or contact lens wear between the keratoconus with hydrops and keratoconus without hydrops groups.[7] It is thought that race does not play a role, but a population-based study done in the United Kingdom showed that the proportion of South Asian and black patients with acute corneal hydrops was significantly higher than in the general population.[8] Although theirs was a small study, Grewal and Laibson reported 21 of 22 (95%) eyes with hydrops seen by a referral cornea service during a 2.5-year period had seasonal allergies, 20 of 22 (91%) eyes had allergy-associated eye-rubbing behavior, and six patients were able to identify a traumatic inciting event (vigorous eye-rubbing in four and traumatic contact lens insertion in two).[9]

Muro 128 was a topical therapy used for the patient in this case report. Muro 128 is designed to draw out excess fluid from the cornea and reduce swelling. It is available as an eye drop (2% or 5%) or an ointment (5%) that is traditionally used at bedtime. The 2% ophthalmic solution is conventionally used for less severe cases. The 5% solution was chosen by the previous provider given the degree of edema. There are mixed opinions about the use and efficacy of Muro 128. A common misconception is that if a keratoconic patient presents with corneal hydrops, topical therapy with Muro 128 ophthalmic solution is required to resolve the edema. If epithelial edema is present, there would be some validity in its use. The hypertonicity allows for an osmotic gradient to occur, allowing fluid to be drawn out of the corneal layers above Bowman's membrane. If the edema is localized in the stroma, Muro 128 drops will have less of an effect. For stromal edema, the endothelial pumps are the main

mechanism for drawing out fluid.[10] Nonetheless, some clinicians use a hypertonic solution to resolve any corneal edema, and reports of efficacy are mixed. In retrospect, I would have not prescribed Muro 128 because the patient did not have any frank epithelial edema.

Patients commonly complain of irritation with Muro 128, as did this patient ("gritty sensation"). Therefore, it is important to make an informed decision about prescribing it based on its tolerability and efficacy. A sensation of burning and stinging (or in this case a "gritty sensation") can be attributed to the hypertonic solution creating an unstable tear film. Hyperosmolar levels in the tear film can result in corneal inflammation and trigger sensory neurons.[11] Given the patient's complaints while using the drop, it was determined best to discontinue.

For patients who present without evidence of epithelial compromise, prescribing a topical nonsteroidal anti-inflammatory or steroid drop three-to-four times per day may provide relief from pain and inflammation. A topical cycloplegic could be prescribed in lieu of, or together with, a steroid to reduce pain and reduce the possibility of a secondary anterior chamber reaction. One may opt not to prescribe a steroid as it may slow corneal healing and lead to a rare corneal perforation. However, in the later stages of healing, when edema has been reduced, a steroid may aid in decreasing scarring.[12] After a trial of Muro 128, a steroid was prescribed for this patient due to his complaints of glare and sensitivity, which were attributed to the dense stromal edema. A less potent steroid, Lotemax Gel, was used instead of the traditional prednisolone acetate ophthalmic suspension 1%, as the patient was told to use it four times a day over the next month. Lotemax was developed to rapidly metabolize to inactive metabolites with the goal of minimizing side effects, so its versatility and safety allows its use for chronic therapy.[13]

Concerns to consider regarding longer-term use of topical steroids include increased IOP, cataract formation and overall suppression of the immune response. A review by Jones and Rhee showed that when treated with topical steroids for four to six weeks, 5% of the population demonstrated a rise in IOP greater than 16 mmHg and 30% had a rise of 6-15 mmHg. A study included in the review showed that IOP returned to baseline or normal approximately one week after discontinuation of steroid treatment.[14] As the patient in this case report did not have any predisposing conditions (a personal or family history of glaucoma, younger child or older adult, type-1 diabetic, history of connective-tissue disease, or high myopia), there was less concern about use of a steroid eye drop for this period of time.

Nonetheless, other methods for measuring IOP, such as the Icare tonometer (Icare USA), should have been utilized. This tonometer would have allowed the student intern or provider to precisely and repeatably measure an area of the cornea that may correlate closely with topography (e.g., the thinnest location). A study from Northern Ireland explored the relationship between IOP measurements and topographical variations in corneal curvature and corneal thickness. For the 49 keratoconic eyes studied, the median central pachymetry and IOP values were 495 µm and 10 mmHg, respectively. The median temporal and nasal pachymetry and IOP values were 621 µm and 641 µm, and 14 mmHg and 13 mmHg, respectively.[24] This study suggests that the Icare tonometer could perhaps offer more precise measurements of IOP because it can be utilized over the thinnest area of the cornea.

Other topical drops that could be used in this scenario are artificial tears and antibiotics (if the epithelium is compromised). With epithelial compromise, a topical, broad-spectrum antibiotic (such as ciprofloxacin hydrochloride ophthalmic solution 0.3% up to four times-a-day) for prophylactic coverage could be prescribed. A broad-spectrum antibiotic ointment, such as erythromycin, also could be recommended for overnight use. Research indicates that use of topical medications only is considered a conservative approach. Corneal perforation is a rare occurrence, and various case reports have shown that patients can be managed conservatively over several days with aqueous suppressants, pressure patching and bandage soft contact lenses until resolution.[15]

During the resolution phase of corneal hydrops, corneal neovascularization is a potential complicating factor. Neovascularization of the cornea is a serious concern when the site of hydrops is near the limbal vasculature. Topical steroid drops should be prescribed to inhibit the reaction, and, should worsening occur, systemic steroids may be indicated. In some of the cases reported, the neovascular response began two to four weeks after the onset of hydrops, an important reason for perhaps monitoring these patients monthly.[16]

In cases of acute hydrops, a relatively new management approach — intracameral injection of gas/air to reduce the duration of corneal edema — has been used. The purpose of injecting gas/air is creating a barrier to prevent the aqueous humor from passing through the ruptured Descemet's membrane into the stroma. Blocking the intrusion of aqueous humor into the stroma would allow for faster healing of the corneal endothelial cells over the exposed stroma, and deposition of the new Descemet's membrane.[17] Miyata and Tsuji evaluated air injection as a barrier between the endothelial cell layer and aqueous humor. They monitored measures such as how long the corneal edema lasted, the length of time between the onset of hydrops and when the eye could wear a gas permeable (GP) contact lens again, and the best-corrected visual acuity with a GP lens after the edema

had subsided. A control group was utilized for comparison. The results showed that the average duration of corneal edema was 20.1 days in the intracameral air injection group and 64.7 days in the control group. The average length of time between the onset of hydrops and when the eye could wear a GP contact lens again was 33.4 days in the intracameral air injection group and 128.9 in the control group. Best-corrected visual acuity with a GP lens after the edema had subsided ranged from 20/50 to 20/25 in the air injection group and from 20/100 to 20/25 in the control group. The researchers noted the intracameral air injection induced no complications.[17]

Gas, either perfluoropropane ($C_3F_8$) or hexafluoride ($SF_6$), is another potential barrier injection. Basu and Vaddavalli studied utilizing $C_3F_8$ gas injected between the endothelial cell layer and anterior aqueous face. Their primary outcome measure was average time to resolution of corneal edema, calculated both from the date of onset of hydrops and the date of initiation of therapy. Results showed the average time to resolution, both from the date of onset of symptoms and from the date of initiation of therapy was significantly lower in the study group than in the control group, which received no surgical intervention (90.5 days vs. 125 days and 78.7 days vs. 117.9 days, respectively).[18]

Panda and Aggarwal studied utilization of $SF_6$ gas as a barrier. Although they studied a smaller patient population, corneal edema resolved at four weeks in the treatment group and not until 12 weeks in the control group.[19] Despite the development of complications such as pupillary block and increase in IOP, the $SF_6$ gas injection treatment was deemed effective. It has been found that surgical intervention is a relatively safe and successful therapy for the early reduction of corneal edema, whether with air or gas.

Severity of visual acuity reduction depends on the size and location of the break in Descemet's membrane and subsequent edema. Most patients, before the development of hydrops, wear some form of GP contact lens correction. When hydrops develops, contact lens wear must be discontinued due to the irregular corneal surface and edema. If epithelial defects are present, any abrasiveness from a flat fitting or low clearance contact lens can exacerbate discomfort. As the area of edema heals and scar tissue forms, the previous area of steepening (usually somewhere within in the cone) will flatten. This flattening effect can sometimes aid in vision if the scarring does not occur centrally, and it can make contact lens fitting easier.

The Collaborative Longitudinal Evaluation of Keratoconus study showed that rigid contact lens wear at baseline, regardless of how the lenses were fitted (steep, aligned or flat), was associated with incident corneal scarring. Although a greater proportion of the corneas wearing flat-fitting contact lenses were scarred, after controlling for disease severity, the risk of corneal scarring did not increase with flat vs. steep rigid contact lens fit.[25] Due to fit and comfort issues, clinicians may elect to proceed with scleral lenses, which allow for complete vaulting of the cornea. This fit can protect the cornea from irritation secondary to a contact lens. If hydrops caused a central scar, penetrating keratoplasty (PK) may be a suitable option to maximize visual potential.

Tuft and Gregory showed that the development of hydrops in eyes with keratoconus was a significant risk factor for subsequently receiving a PK, and at the end of the study period 87 of the 147 eyes studied (59%) had surgery for visual rehabilitation.[20] Grewal and Laibson showed that various medical therapies did not differ significantly with regard to outcome, and ultimately 4 of 22 patients (18%) underwent a PK.[9] Tuft and Gregory also showed that the same studied eyes that underwent a PK had a greater rate of graft rejection than eyes grafted without hydrops.[20] But Fan Gaskin and Good with the Auckland keratoconus study found no statistically significant differences in the overall corneal transplantation rate between the two studied groups (subjects with keratoconus and corneal hydrops over a 17-year period compared with an age- and gender-matched control group of subjects with keratoconus but no prior history of corneal hydrops).[7] Basu and Reddy showed that the risk of endothelial rejection episodes was greater in eyes with longer duration of corneal hydrops and co-existent ocular allergy. Also, although endothelial rejection episodes are more common in eyes with resolved corneal hydrops, long-term allograft survival and visual results after PK are similar in eyes with keratoconus with and without prior corneal hydrops.[21]

**Conclusion**

A standard of care for the management of corneal hydrops, employing either topical ophthalmic medications or surgical intervention in the form of an intraocular injection, has yet to be established. A logical approach to treatment is to reduce the patient's symptoms and expedite corneal healing.

Conservative management of corneal hydrops with topical treatment may take two to four months for complete resolution, while a surgical approach may shorten that time. Although surgical intervention leads to a faster resolution, topical management is less invasive and presents minimal complications. With either modality, the final vision result will be similar. Perhaps size, location and amount of edema should dictate which method of treatment would be most effective. If the hydrops is off-center and patient complaints are minimal, a conservative approach of topical therapy may suffice. Conversely, if the

edema is large in diameter and central, and central scarring affecting visual acuity status post healing is a concern, referral to a cornea specialist for surgical intervention may be warranted.

This condition can initially be quite uncomfortable and visually disabling to the patient. However, once the area of hydrops has resolved and the previous ectatic area is flatter, vision may actually be better than prior to onset (as it was for the patient in this case report, who had post-hydrops spectacle-corrected visual acuity of $20/50^{+1}$ vs. $20/60^{-2}$ pre-hydrops). Post-hydrops fitting with scleral contact lenses — bridging the patient's unique corneal curvature — may be the best opportunity to increase vision potential, although corneal GP lenses may be easier to fit with a new, flatter curvature. If scarring is severe centrally once the edema has resolved, vision may not improve regardless of the contact lens type selected. A referral to a cornea specialist for a cornea transplant may be warranted.

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# Assessment of Competency Following Use of Eyesi Indirect Ophthalmoscope Simulators Within a First-Year Optometric Curriculum

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PDF of Article

**Background**

Healthcare education has historically operated under the adage of, “See one, Do one, Teach one,” a phrase coined after Halsted’s depiction of early surgical residency training.[1] In reality, Duvivier et al. found that medical students require repetitive practice to reach competency.[2] For optometry students, competent operation of the binocular indirect ophthalmoscope is a skill that requires many hours of practice. Binocular indirect ophthalmoscopy (BIO) is a difficult skill because it requires knowledge of anatomy, proper alignment of the optics and fine motor dexterity, all while navigating an inverted retinal image. Traditionally, students reach competency through classroom instruction, hands-on laboratory sessions with faculty and many hours of practice with peers.

Ericsson et al. hypothesized the path to mastery was not solely based on the amount of time spent practicing, but the amount of practice time devoted to targeting specific aspects of performance, which he termed deliberate practice.[3] Deliberate practice requires students to:

1. break the task down to the individual skills required to become competent
2. engage in tasks that provide immediate feedback on performance
3. persevere with increasingly more challenging tasks until the intended cognitive or psychomotor skills are achieved

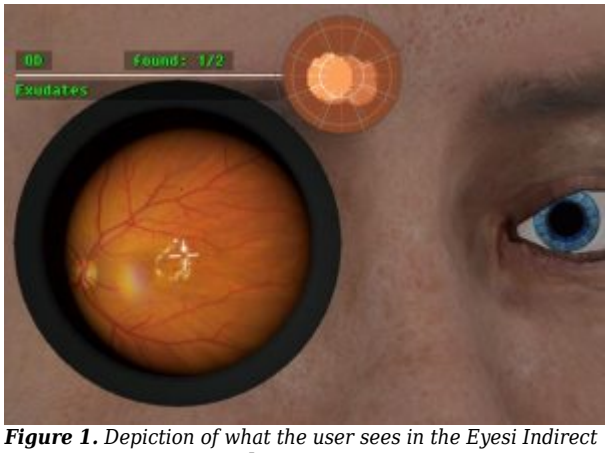



***Figure 1.*** *Depiction of what the user sees in the Eyesi Indirect Ophthalmoscope headset.*[7] *Click to enlarge*

***Figure 2.*** *Students using the Eyesi Indirect Ophthalmoscope.*
*Click to enlarge*

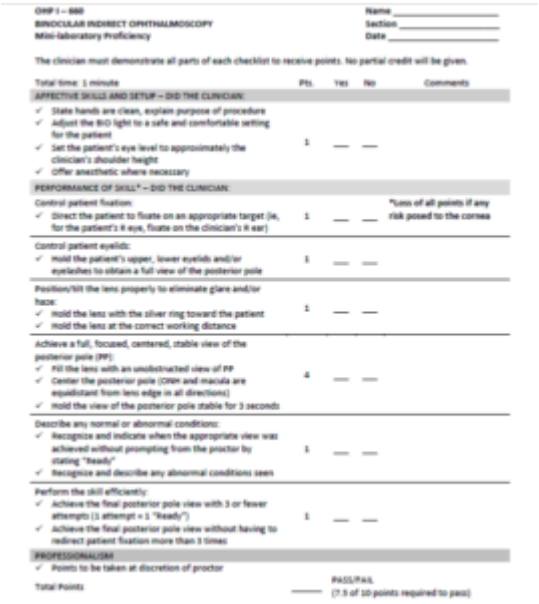
The use of simulations in healthcare education has increased due to concerns for patient safety, necessity of exposing students to rare clinical scenarios and a need for repeated practice of clinical skills within a standardized experience. Issenberg et al. defined simulation-based medical education (SBME) as an individualized learning opportunity for students to acquire and practice clinical skills in an environment that imitates real patient encounters, anatomic regions or representative clinical tasks.[4] High-fidelity medical simulations facilitate learning through timely feedback and engagement in activities that reinforce and challenge the student, contain well-defined learning objectives and are representative of clinical practice. McGaghie et al. performed a meta-analysis and concluded that SBME with deliberate practice was superior to traditional clinical medical education in achieving skill acquisition.[5] Hayden et al. found that incorporating high-quality simulation experiences could replace up to half of traditional clinical education opportunities with no deleterious effect on outcomes.[6] Advances in virtual reality have provided more realistic and immersive environments for SBME. The Eyesi Indirect Ophthalmoscope is a high-fidelity virtual reality simulator for training of the BIO skill. When wearing the Eyesi headset, the student is able to view a binocular rendering of the anatomical structures of the retina **(Figures 1 and 2)**. The Eyesi curriculum contains four modules designed for students to independently learn basic BIO navigation and documentation and visualize common pathologies such as age-related macular degeneration and diabetic retinopathy.[7]

During the spring quarter of the 2015-2016 academic year, first-year students were tasked to complete Tiers A and B within the Eyesi Indirect Ophthalmoscope curriculum. The purpose of this study was to evaluate whether these students were able to perform BIO to a competent level following 10 weeks of independent study with the Eyesi Indirect Ophthalmoscope.

## Methods

*Previous class-year instruction*

For the three previous academic years (2013-14, 2014-15, and 2015-16), the BIO skill was first introduced to students in the Ocular Health Procedures I course in the fall quarter of their second year. In this course, students received a total of four hours of lecture (two hours of lecture per week) along with six hours of laboratory instruction (three hours per week) on the BIO skill. In addition, students were provided with after-hours practice sessions staffed by third-year optometry teaching assistants seven days a week for three hours each session. During the third week, students were administered the Posterior Pole Mini Proficiency (PPMP), which was used to evaluate their competency in obtaining full views of the posterior pole of the retina. **Figure 3** shows the rubric in which students were evaluated with a total of 10 points possible and requiring a minimum score of 7.5 points to have demonstrated competency.



OHP I – 660
BINOCULAR INDIRECT OPHTHALMOSCOPY
Mini-laboratory Proficiency

Name _____
Section _____
Date _____

The clinician must demonstrate all parts of each checklist to receive points. No partial credit will be given.

| Total time: 1 minute | Pts. | Yes | No | Comments |
|---|---|---|---|---|
| **APPETIVE SKILLS AND SETUP – DID THE CLINICIAN:** | | | | |
| ✓ State hands are clean, explain purpose of procedure<br>✓ Adjust the BIO light to a safe and comfortable setting for the patient<br>✓ Set the patient's eye level to approximately the clinician's shoulder height<br>✓ Offer anesthetic where necessary | 1 | ___ | ___ | |
| **PERFORMANCE OF SKILL* – DID THE CLINICIAN:** | | | | |
| Control patient fixation:<br>✓ Direct the patient to fixate on an appropriate target (ie, for the patient's R eye, fixate on the clinician's R ear) | 1 | ___ | ___ | *Loss of all points if any risk posed to the cornea |
| Control patient eyelids:<br>✓ Hold the patient's upper, lower eyelids and/or eyelashes to obtain a full view of the posterior pole | 1 | ___ | ___ | |
| Position/tilt the lens properly to eliminate glare and/or haze:<br>✓ Hold the lens with the silver ring toward the patient<br>✓ Hold the lens at the correct working distance | 1 | ___ | ___ | |
| Achieve a full, focused, centered, stable view of the posterior pole (PP):<br>✓ Fill the lens with an unobstructed view of PP<br>✓ Center the posterior pole (ONH and macula are equidistant from lens edge in all directions)<br>✓ Hold the view of the posterior pole stable for 3 seconds | 4 | ___ | ___ | |
| Describe any normal or abnormal conditions:<br>✓ Recognize and indicate when the appropriate view was achieved without prompting from the proctor by stating "Ready"<br>✓ Recognize and describe any abnormal conditions seen | 1 | ___ | ___ | |
| Perform the skill efficiently:<br>✓ Achieve the final posterior pole view with 3 or fewer attempts (1 attempt = 1 "Ready")<br>✓ Achieve the final posterior pole view without having to redirect patient fixation more than 3 times | 1 | ___ | ___ | |
| **PROFESSIONALISM** | | | | |
| ✓ Points to be taken at discretion of proctor | | | | |
| Total Points | ____ | PASS/FAIL (7.5 of 10 points required to pass) | | |

*Introduction of the Eyesi BIO simulators*

During the spring quarter of the 2015-2016 academic year, first-year optometry students were tasked with completing Tiers A and B within the Eyesi curriculum in the Optometric Clinical Services I course. The intent of placing the simulators in the first-year curriculum, prior to traditional

instruction, was to reduce the need for faculty instruction on the BIO skill.

Students completed an online learning module and a hands-on demonstration designed to familiarize them with basic handling of the simulators. In addition, students reviewed an online video tutorial on how the BIO skill is performed on a live patient and were allocated three hours of practice time every other week for a 10-week period to complete the tiers of the Eyesi Indirect Ophthalmoscope curriculum.

***Figure 3.*** *Scoring rubric for the Posterior Pole Mini Proficiency (PPMP) and the Pre-Lab Mini Proficiency (PLMP). Click to enlarge*

In Tier A **(Figure 4)**, students were taught the basic handling of the indirect ophthalmoscope as well as how to maneuver to obtain the desired views. They were tasked to obtain a view of the retina (starting with posterior pole) and to move the viewfinder crosshairs over geometric shapes within the retinal image **(Figure 5)**. In Retina Screening, students learned the location of anatomical structures within the retina by searching for and placing the viewfinder crosshairs over specific anatomical structures. In Retina Documentation, students were tasked to find and document the location, orientation and size of abstract objects in order to understand the true location of the inverted images (Figure 5). At the end of each training case, students were provided a report card on how well they completed the task **(Figure 6)**.

In Tier B **(Figure 7)**, students were provided with images of normal retinas from various cases. They worked through the teaching and exam modes, which tasked them to identify anatomical features and classify characteristics of healthy retinas. Students who needed additional time to complete the tiers were provided access to the simulators during non-scheduled hours. The instructor of record of the Optometric Clinical Services I course evaluated the students' progress via the online portal to ensure all students completed the assigned tiers by the end of the spring quarter.

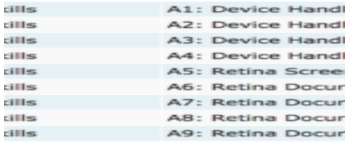



***Figure 4.*** *Description of Tier A within the Eyesi Indirect Ophthalmoscope simulator curriculum.[7] Click to enlarge*

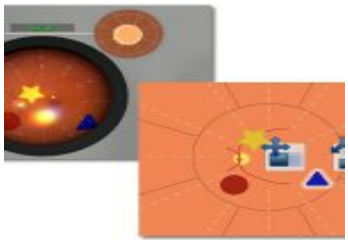


***Figure 5.*** *Example of abstract objects in Tier A.[7] Click to enlarge*

***Figure 6.*** *Example of end-of-case feedback report to the student. Click to enlarge*

***Figure 7.*** *Description of Tier B within the Eyesi Indirect Ophthalmoscope simulator curriculum.[7] Click to enlarge*

After the summer break, the students (now second-year) were enrolled in the Ocular Health Procedures I course during the fall quarter of the 2016-2017 academic year. At the start of the fall quarter, the students were administered a Pre-Lab Mini Proficiency (PLMP) prior to receiving any laboratory instruction on the BIO skill. The PLMP was identical to the PPMP, and the same rubric was used for grading (Figure 3). Students then received the same traditional BIO instruction and practice sessions as described above for previous classes, including taking the PPMP during the third week.

*Data collection and analysis*

The mean scores on the PPMP for the three previous class years were compared to the mean score of the 2016-2017 class using ANOVA. Also, the mean score on the PLMP exam for the 2016-2017 class was compared to its mean score on the PPMP using a paired t-test. The percentage of students who demonstrated competency (at least 7.5 of 10 points) on the PPMP (and PLMP for the 2016-2017 class) was recorded for the four classes.

**Results**

During the spring quarter of the first-year, 99 students completed Tiers A and B within the Eyesi curriculum. During the subsequent fall quarter, the students were enrolled in the Ocular Health Procedures 1 course where 5% of the class reached competency (defined as a minimum score of 7.5 out of 10 points on the PLMP). The mean score for the class was 2.46±2.08 on the PLMP **(Table 1)**.

After instruction and practice, students took the PPMP where the 2016-2017 class achieved a mean score of 8.55±1.94 (paired t-test $p<0.001$) and 82.82% of the class reached competency. Based on ANOVA, with statistical significance set at a p-value less than 0.05, the PPMP score was not statistically different ($p=0.283$) from the scores of the previous classes.

**TABLE 1**
**Performance on the PLMP and PPMP**

| | PLMP Mean Score | % of Class Achieving BIO Competency (at least 7.5 out of 10 points) | PPMP Mean Score | % of Class Achieving BIO Competency (at least 7.5 out of 10 points) |
|---|---|---|---|---|
| Fall, 2016-17 AY | 2.46 (±2.08) | 5% | 8.55 (±1.94) | 82.8% |
| Fall, 2015-16 AY | N/A | | 8.83 (±1.975) | 82.0% |
| Fall, 2014-15 AY | | | 8.43 (±1.806) | 77.9% |
| Fall, 2013-14 AY | | | 8.32 (±2.038) | 74.0% |

*PLMP = Pre-Lab Mini Proficiency; PPMP = Posterior Pole Mini Proficiency*

***Table 1.*** *Click to enlarge*

## Discussion

Based on the comparison of the PLMP score to the PPMP score, as a standalone instruction method for teaching the BIO skill, the EyeSi curriculum was not able to teach students to obtain a full, in-focus and stable view of the posterior pole to a competent level. These results differ from previous reports in which a positive learning outcome was associated with the incorporation of the EyeSi Indirect Ophthalmoscope.[8-13] Rai et al. found that novice ophthalmology residents who received instruction through the EyeSi Indirect Ophthalmoscope outperformed their colleagues who had received traditional BIO training with didactic lecture and practicing BIO under supervision.[12] This conclusion was based on the residents' performance score derived from the EyeSi Indirect Ophthalmoscope, which factored in accurate documentation, amount of retina visualized, elapsed time and the ability of the residents to identify and maintain views of posterior segment structures. However, it is likely that the familiarization of training on the simulators had an effect on performance scores because the conventional training group also had improvement in performance following an opportunity to receive training on the simulators. Anderson et al. reported a greater number of students achieving a 100% score in visualizing the mid-periphery and posterior pole with their BIO assessment when they were assigned to complete Tier A of the EyeSi curriculum as a supplement to traditional faculty-led instruction.[11] In their subsequent course administration, a portion of Tier A was assigned to the students prior to the course, similar to our course design. Anderson et al. observed that student learning had been accelerated. As a result, to better challenge and further assess students' BIO ability, they altered their assessment to include full views in nine peripheral locations.[11] In our study, the timing of the PPMP was the same as in previous course administrations; therefore, we were unable to assess whether the students' competency in BIO had been accelerated.

Issenberg et al. identified feedback as the single most important feature of simulation-based medical education.[4] After completing Tiers A and B of the EyeSi curriculum (Figure 4 and 7), students learned to obtain views of the retina with the indirect ophthalmoscope. However, the limitation of the EyeSi curriculum was its inability to provide feedback on the other dimensions of the PLMP rubric (Figure 3), such as hand-washing, ability to hold a full view for at least three seconds, manipulation of a patient's lids and lashes and adjustment variables such as chair height and patient fixation angles.

*Limitations*

A limitation of our study was the timing of the PLMP. Students' skills were subject to degradation over the summer break. It is possible that a larger proportion of students would have passed the PLMP if it had been administered at the conclusion of the spring quarter of their first-year. Although the instruction of the BIO skill was similar across each course administration, the cohorts of students were different, which could have affected the outcome of our study.

## Conclusion

The EyeSi Indirect Ophthalmoscope is a high-fidelity simulator that provides a realistic student training experience, opportunity for continuous practice, tracking of skill acquisition and introduction to a wide array of common and rare vitreoretinal pathology. The simulator adopts the principles of deliberate practice, which may accelerate competency

attainment and assist in reducing the achievement gap between students' performance. Cham and Cochrane hypothesized that introduction of the EyeSi Indirect Ophthalmoscope would help students reach technical competency sooner, which would reduce teaching workloads by minimizing the need for intensive faculty-led instruction on the BIO procedure.[13] Based on our work and the work of Anderson et al. and Rai et al., the EyeSi Indirect Ophthalmoscope is best utilized as an adjunct to faculty-led instruction, not as a replacement for faculty instruction.[11,12] Additional applications for the EyeSi Indirect Ophthalmoscope simulator may be as a tool to reduce erosion of skill over time, to simulate clinical decision-making (Eyesi curriculum Tiers C and D) and to reduce the rigors and consequences associated with repeated dilations on one another.

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