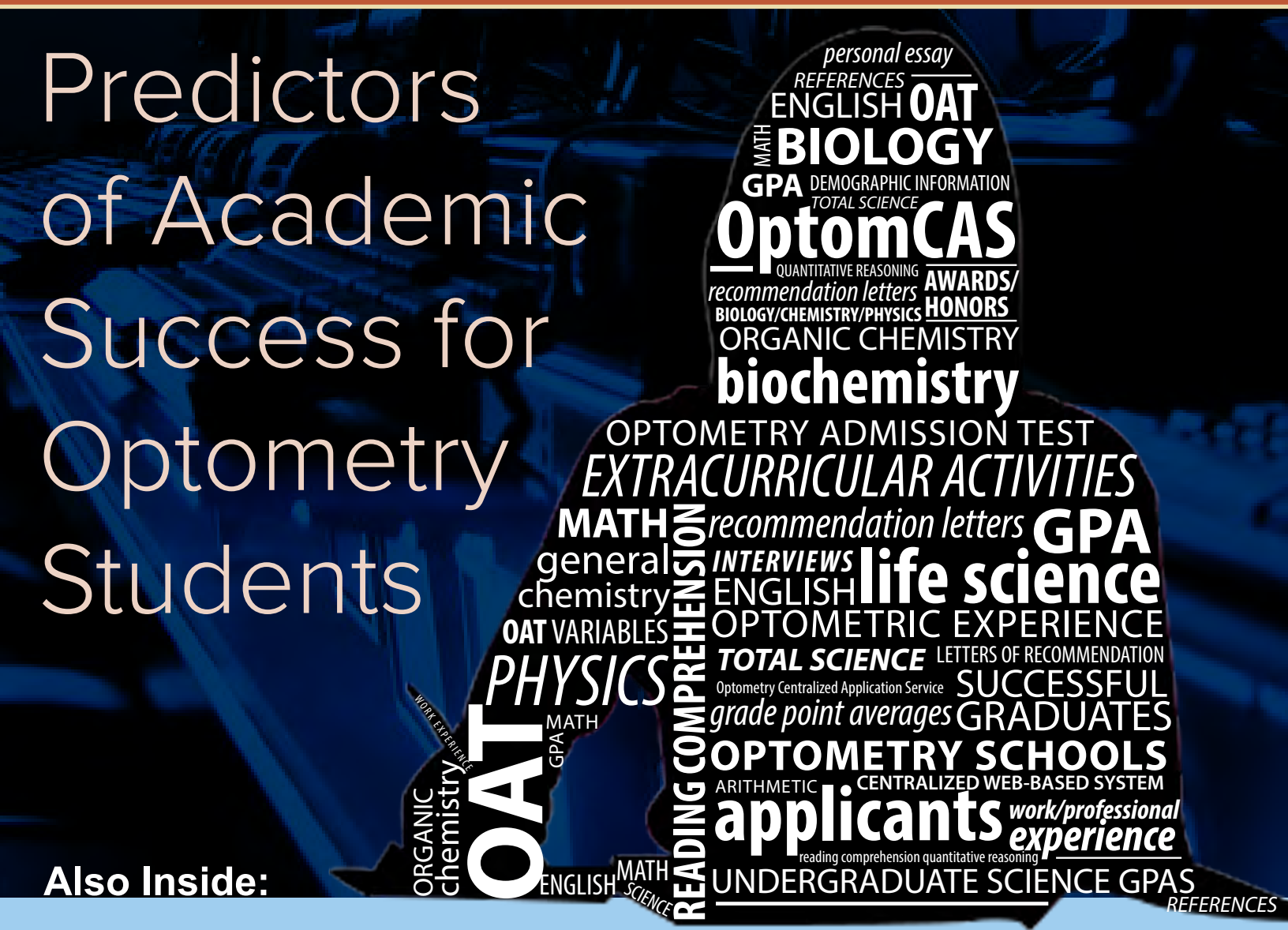
The Journal of the Association of Schools and Colleges of Optometry

OPTOMETRIC EDUCATION

Volume 38, Number 3 Summer 2013

Predictors of Academic Success for Optometry Students



Also Inside:

- Impact of Interactive Instructional Tools in Gross Anatomy for Optometry Students: a Pilot Study
- Value Added Assessment of Private Practice Externships
- Carbon Monoxide and the Eye: A Teaching Case Report
- Recipients of ASCO Starter Grants for Educational Research and the Dr. Lester Janoff Award for Writing Excellence Announced
- ASCOTech: Open Access Publishing, Opportunities and Challenges

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The Association of Schools and Colleges of Optometry (ASCO) represents the professional programs of optometric education in the United States. ASCO is a nonprofit, tax-exempt professional educational association with national headquarters in Rockville, MD.

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Past issues of Optometric Education *are available on the ASCO Web site at http://www.opted.org/newsroom-media/optometric-education/view-past-issues/. Funding for archiving was generously provided by Transitions Optical.*

ARTICLES

Predictors of Academic Success for Students at the Michigan College of Optometry
Robert S. Buckingham, OD, PhD
Sara R. Bush, OD
Optometry school admission committees must choose students based on their predictions of the applicants' success. This study evaluates the predictive value of the Optometry Centralized Application Service (OptomCAS) variables. Each undergraduate course taken by students entering the Michigan College of Optometry at Ferris State University was categorized according to the OptomCAS variables. Linear regression analysis found that the OAT academic average and reading comprehension as well as other undergraduate GPAs are the best predictors for academic success. No academic variables could predict graduation. This study provides optometry admission committees additional tools for improving their selection process. 92

Impact of Interactive Instructional Tools in Gross Anatomy for Optometry Students: a Pilot Study
Patricia C. Sanchez-Diaz, DVM, PhD
New technologies are having a tremendous impact on the way we learn and teach. Virtual resources have become a popular way to enhance lecture and laboratory instruction. In fact, virtual dissections and 3D interactive anatomical models, which aim to provide visualization and a better understanding of the potential clinical implications of anatomical dysfunction, are emerging as convenient supplementary methods, or even substitutes, for the use of cadavers. However, there is no experimental data assessing their effectiveness in optometry. This study evaluated the effects of different interactive strategies on student motivation and learning outcomes. Sixty-five optometry students were assigned to control and intervention groups for the anatomy laboratory. Post-laboratory quizzes and questionnaires were used as assessment tools. Results sug-

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gested that the use of supplementary audiovisual resources and virtual 3D models, along with the creation of critical-thinking questions and clinical scenarios, may enhance the laboratory instruction in anatomy by promoting student motivation. The results obtained with this pilot study may allow us to apply similar strategies in more clinical courses in optometry and possibly in other health sciences programs. **100**

Value Added Assessment of Private Practice Externships
Diane T. Adamczyk, OD, FAAO
Rochelle Mozlin, OD, MPH
Private practice settings provide important educational experiences for optometry students, with opportunities for both clinical and practice management exposure. Challenges exist for both the private practice and the affiliated educational institution. These challenges include assuring an appropriate educational experience for the student, integrating the extern into the practice, and developing the private practice preceptor into a clinical educator.

This project assessed what components are important in establishing "Optometric Centers of Excellence for Private Practice Specialty Education" and compared the specialty (vision therapy/pediatric) private practice experience with an institutionally based specialty externship. The specialty private practice externships were found to have a value added component that included a broader patient population, greater variety of clinical education opportunities, and increased understanding of practice management skills. **106**

Carbon Monoxide and the Eye: A Teaching Case Report
Todd Peabody, OD, MBA, FAAO
Amanda Furr, OD
Nash Ditmetaroj, OD
Both acute and chronic exposure to carbon monoxide (CO) gas can have serious and permanent effects on a person's health and vision, especially if left untreated. The brain and eyes are at risk upon exposure to this clear, odorless gas due to the large oxygen demands of these structures. This teaching case report highlights the need for eyecare professionals to recognize the possible ocular, systemic and neurological effects of CO poisoning and the impending long-term risk factors. This report also reviews the body's response to acute hypoxic events, including ocular and systemic symptomatology, the testing and procedures used for the differential diagnosis of CO poisoning, the events and risk factors leading to CO poisoning, the pathophysiology of CO on the body, and the treatment options for CO poisoning from the perspective of an eyecare provider. **114**

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INDUSTRY NEWS

The following companies support ASCO's national programs and activities benefiting the schools and colleges of optometry in the United States and Puerto Rico.*

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As of January 1, 2013

New Portable A-Scan Solution Unveiled

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Accutome introduced the A-Scan Plus Connect, a compact and efficient tool for measuring axial length prior to cataract surgery, in a mobile laptop/PC compatible platform. The Connect can link directly to a PC, laptop or tablet device. In addition to its direct-connect ability, the new instrument features an improved and easy-to-upgrade software interface and calculation menus. Information can easily be uploaded to electronic medical records systems and shared with the company's B-Scan Plus and UBM Plus devices.

Accutome specializes in portable ophthalmic equipment and also offers more than 6,000 clinical supplies and medications. The company recently unveiled a new e-commerce Web site. For more information, visit www.accutome.com, e-mail info@accutome.com, or call (800) 979-2020.

National Competition Participants Chosen

Walmart

Walmart announced the regional winners in its 2012-2013 Project Foresight optometry scholarship competition in which student teams from ASCO member schools design an "Optometric Practice of the Future," which promotes the profession of optometry and the values and vision of Walmart & Sam's Club Health and Wellness.

The regional winners, who receive a team scholarship of $1,500 and a travel grant to attend and the opportunity to compete in the National Project Foresight Scholarship Competition during the AOA meeting in San Diego, are:

- Southern College of Optometry: Enrique Palacios and Frank Carusone
- MCPHS University School of Optometry: Marie Mantelli and Kathryn Surdovel
- MCPHS University School of Optometry: Charles Engelbrecht and Prathik Philip
- The Ohio State University College of Optometry: Abigail Graeff and Marcella Pipitone
- Michigan College of Optometry at Ferris State University: Ramon Yalldo and Lou Greco
- NOVA Southeastern University College of Optometry: Blake Dornstauder and Rhea Butchey
- NOVA Southeastern University College of Optometry: David Dada and Sara Berke-Silva
- Inter American University of Puerto Rico School of Optometry: Dominique Oker and Ratidzo Macharaga
- Pacific University College of Optometry: Shane McDonald and Jona Johnson
- Indiana University School of Optometry: Danielle Richardson and Kinjal Bhatt
- New England College of Optometry: Esther Yang and Mary Vivirito.

The winners of the national competition were to be announced on June 28, not in time to be included in this issue of the journal. The first-place winner receives a $15,000 team scholarship, and the second-place winner receives a $5,000 team scholarship.

FDA Approves Tecnis Toric 1-Piece IOL

The FDA approved a new post-cataract surgery IOL from Abbott, the Tecnis Toric 1-Piece IOL. The new lens can correct loss of focus due to pre-existing corneal astigmatism of 1.0D or greater. Because it is built on the Tecnis aspheric platform, it also minimizes spherical aberration to provide patients with sharp distance vision.

According to Abbott, the Tecnis Toric 1-Piece IOL remains very stable once inserted into the eye and meets the American National Standards Institute's new standard for toric IOL rotational stability. Additional information is available at www.tecnistoriciol.com.

Portable Camera Available for Trial

A new portable retinal camera from Volk is available for a 3-week trial. Weighing just 1 lb., the new camera captures non-mydriatic high-resolution jpeg images of the retina that can be downloaded to any PC.

The trial is intended to provide training and support so that users can fully realize the technical and economic benefits the camera can provide. To arrange a free trial, call (800) 345-8655.

Scleral Lens Now in 16-mm Design

Visionary Optics LLC, an authorized lab for Bausch + Lomb's Boston contact lens materials, now offers a 16-mm version of its Europa Scleral lens. The Europa is a next-generation design based on the company's Jupiter Scleral technology. It capitalizes on the design tenets of a true scleral lens with the goal of improving fit and comfort. A modified scleral zone and enlarged optic zone are designed to optimize scleral landing and improve corneal vault. The new design also incorporates a reverse curve to fit a wider range of corneas, simplifying the fitting process.

The new lens is available in both a seven-lens and 14-lens diagnostic fitting set. For more details, call (877) 533-1509.

Data Management App Released for iPad

Carl Zeiss Meditec has extended its Forum Archive & Viewer data management system for ophthalmology and optometry to include an app for iPads. The new software application allows doctors to have convenient and secure access to their diagnostic patient data wherever and whenever they may want it.

The app solution utilizes the simple, intuitive iPad interface and enhances the diagnostic workflow because data access is no longer limited to stationary computers.

The company also announced that it received the NorthFace ScoreBoard Award from the Omega Management Group Corp. in recognition of achieving excellence in customer service in 2012. This is the tenth consecutive year it has been honored with the award. For more information, visit www.meditec.zeiss.com.

List of Practice Tools for Optometry Grows

The Vision Care Institute LLC, part of the Johnson & Johnson family of companies, is expanding its ODLean Consulting Program to better help eyecare practitioners manage patient flow, increase productivity, improve patient experience and boost profits.

By attending the new one-day seminar, Operating a Lean Practice, doctors and their staff members can learn to improve patient scheduling and clinical balance and implement communications techniques for effective patient hand-off from technician to doctor and from doctor to optician. The seminar is being conducted in multiple locations across the country at a fee of $350 per attendee.

The expanded offerings also include a series of e-learning modules, ranging in length from 5 to 20 minutes, which will be available through www.ODLean.com starting in mid to late 2013. Also in mid to late 2013, users of the iPad application ODLean Patient Experience will be able to send patient flow data to a Web portal where they can access their metrics.

For more information, including seminar locations and registration, visit www.ODLean.com.

New Awards Program Supports Researchers

CooperVision launched a Science and Technology Awards Program to provide scientists in academia and research institutes a substantive opportunity to pursue emerging ideas and concepts. The program focuses on ocular surface health and anterior segment symptomology through advancement of technologies including, but not limited to, materials, devices and compounds. It consists of the CooperVision Seedling Award and the CooperVision Translational Research Award.

The Seedling Award is intended to incentivize collaborations with CooperVision in a new research area for a one-year period. It enables investigators to generate preliminary data that could be used toward a future Translational Research Award. The award provides funding for one year and is awarded on a one-time basis only at a maximum total cash amount of $100,000, including indirect costs.

The Translational Research Award is a multi-year award for a substantive translational research project.

Collaboration between basic scientists, engineers and clinicians is strongly encouraged in order to achieve high-quality, innovative translational research. This award provides funding up to $400,000 for up to two years, including indirect costs. A maximum of $250,000 can be requested for any one year. The award may be considered for renewal.

CooperVision strongly encourages early-career and established faculty in areas other than contact lens research to apply. For information about the application process and materials, visit http://coopervision.com/our-company/science-and-technology-awards.

Printed Multicultural Tools a Click Away

Transitions Optical Inc. has made it easier than ever to order printed copies of its multicultural resources through a new online ordering feature at MyMulticulturalToolkit.com, an online resource designed to help practices better understand and meet the needs of their diverse patients. With the click of an "order" button, eyecare professionals can enter their practice information and request to have multicultural resources delivered to their practice, free of charge.

Available materials include white papers, bilingual pocket cards to help eyecare professionals smoothly guide patients through the eyewear selection process, and bilingual guides to the eye appointment.

PDF versions of the multicultural resources can be found at MyMulticulturalToolkit.com. Orders for printed materials are also accepted through Transitions Optical Customer Service directly at cservice@transitions.com or (800) 848-1506.

Technology Bundle Offers Benefits

The Haag-Streit Octopus perimeter can now be bundled with Optovue's optical coherence tomography technology (RTVue and iVue). Optovue will be responsible for sales, installation and training for Octopus in the United States, and Haag-Streit will be responsible for ongoing clinical support and technical service. According to the companies, the bundled technologies "create an advanced package that will provide a superior diagnostic tool," and include "the best of both worlds, offering the optimum structure-function solution."

For more information, visit www.optovue.com or www.haag-streit-usa.com.

Water Gradient CLs Launched in U.S.

Alcon announced the U.S. launch of Dailies Total1, the first and only water gradient contact lens that features an increase from 33% to more than 80% water content from core to surface. At the very outer surface, the water content of the lens approaches 100%. The launch follows more than a decade of research and development to create a daily disposable contact lens that delivers exceptional breathability and comfort that lasts through the entire day.

Dailies Total1 are made from the new delefilcon A water gradient lens material, which combines silicone hydrogel innovation, the latest generation of Alcon's proprietary LightStream lens technology, and advances in surface chemistry. For more information, visit www.alcon.com.

ASCO Thanks Supporters of the Summer Institute for Faculty Development

The Association of Schools and Colleges of Optometry (ASCO) would like to thank the following companies and organizations for generously sponsoring the Summer Institute for Faculty Development, which was held July 14-17, 2013, at the Eric P. Newman Center of the University of Washington Medical Center in St. Louis, Mo.

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This year's program was ASCO's fifth Summer Institute for Faculty Development. David A. Damari, OD, FCOVD, FAAO, Dean of the Michigan College of Optometry at Ferris State University, and Shilpa J. Register, OD, MS, PhD, Dean of the MCPHS University School of Optometry, served as co-chairs. Forty-seven applicants from 22 schools and colleges of optometry were selected to participate in the program.

The Institute is an ASCO initiative designed to support its strategic objective of faculty promotion and development. It provides participants, individuals who have been full-time faculty members for 10 years or less, with knowledge and skills necessary to enhance their success in an optometric academic environment as career-long, productive faculty members, thus contributing to increased retention of faculty in the schools and colleges of optometry. The Institute promotes active learning in a nurturing environment and is comprised of formal presentations, workshops and shared activities in the areas of teaching and learning, scholarship and academic culture. Each attendee develops a long-term career plan with specific goals, objectives and action strategies. Attendees are mentored in this process by the program leadership and other attendees.

ASCO will begin accepting applications for the next Summer Institute for Faculty Development in January 2015. For information, contact Program Manager LaShawn Sidbury, CMP, at lsidbury@opted.org or (301) 231-5944 ext. 3012.

EDITORIAL

Lessons *not* Learned in the Classroom

Aurora Denial, OD, FAAO

My responsibilities as editor of *Optometric Education* include the writing of three editorials per year. Because the journal is the only journal dedicated to optometric education, my editorials usually reflect upon the educational process. In this editorial, I am writing about lessons learned outside of a classroom, lab or clinical environment.

The Boston Marathon is the oldest annual marathon.[1] First run on April 19, 1897, it is always held on Patriots' Day.[1] The link to Patriots' Day is significant because it represents the start of the Revolutionary War and the struggle for liberty.[1] In 1924, the race was lengthened to 26 miles 385 yards, which extended the start of the race to Hopkinton and allowed for conformity to Olympic standards.[1] The first cash prize was awarded in 1986, and the first woman runner was officially allowed to enter in 1972.[2] Past marathons have included events that were scandalous or motivational. The Rosie Ruiz scandal in 1980 officially disqualified the winner after an investigation, which concluded that Ruiz had skipped most of the race.[3] The father and son team of Dick and Rick Hoyt is inspirational: Dick Hoyt has pushed his son Rick, who is afflicted with cerebral palsy and wheelchair-bound, through 30 marathons.[4]

The 2013 Boston Marathon was the 117th running of this famous race.[1] The race started in Hopkinton at 9:17 a.m.[1] The weather was clear with temperatures ranging from the 40s to mid-50s. It was a perfect day to enjoy the excitement and festivities associated with the race. More than 23,000 runners were participating.[1] The winners of the race were Lelisa Desisa (men's division), Rita Jeptoo (women's division) and Hiroyuki Yamamoto (wheelchair division).[5] The New England College of Optometry (NECO) is less than 1 mile from the finish line and even closer to parts of the marathon route. In past years, several of our students, faculty and staff have run in the race. Most of our students live in close proximity to the route of the marathon. Classes are traditionally cancelled on Marathon Day due to the practicality of getting to the area; however, the college is open for fund-raising events.

On April 15, 2013 at 2:50 p.m. EDT, the Boston Marathon experienced unthinkable events that were shocking and colossal. At that time, two explosions occurred on Boylston Street near the finish line of the race. The images of chaos, fear and uncertainty were displayed by the media. The college was immediately evacuated and closed. Several members of the NECO community were at the finish line or in the area. Thankfully none was injured. As everyone knows, three spectators were killed and more than 200 were injured.[6] The following day the college was still closed because it fell within the investigation zone.

The days following the marathon proved to be a sad reminder of the event. My normal route to work was altered because my exit was in the crime zone. A memorial of flowers, memorabilia, etc., outlined Boylston Street as well as the yellow crime tape along the perimeter of the crime scene. The end of the week brought a new level of fear and uncertainty. The alleged suspects were identified, and a surreal chase and shoot-out occurred in the attempt to apprehend them. Neighborhoods in which our students and faculty lived were in lockdown. The college was closed again, the term "shelter in place" echoed over the media. The television stations reported the same information over and over again, yet I could not stop watching it. By Friday evening one suspect was captured, another deceased.[6]

Reflecting on these events leads to emotions, realizations and lessons learned. There are feelings of sadness, horror

and vulnerability associated with the understanding that some events are beyond our control and being in the wrong place at the wrong time could happen to anyone. There is the kindness and heroism of bystanders and first responders helping innocent victims. The generosity and outpouring of concern from Bostonians and in particular the NECO college community is memorable. Our students, faculty and staff who were in such close proximity to these events will have acquired life lessons that will impact them in a unique and personal manner. As faculty we often spend much time preparing our lessons, but on April 15, 2013, lessons were taught that were not learned from the curriculum.

Reference

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✯ Special Announcement ✯

Authors of Tobacco Dependence Education Paper Win 2013 Dr. Lester Janoff Award for Writing Excellence

The winners of the 2013 Dr. Lester Janoff Award for Writing Excellence are Marlee M. Spafford, OD, PhD, Matthew D. Iley, BSc, OD, Annette S.H. Schultz, RN, PhD, and Ryan D. Kennedy, MAES, PhD. The authors received the award for their paper "Tobacco Dependence Education in Optometry: A Canadian Pilot Study Assessing Practices and Opportunities," which was published in the Fall 2010 (Vol. 36, No. 1) issue of *Optometric Education*, the journal of the Association of Schools and Colleges of Optometry.

The Dr. Lester Janoff Award for Writing Excellence recognizes the outstanding writing of a research article published in the journal. It is named in honor of the late Lester E. Janoff, OD, MSEd, FAAO. Dr. Janoff was editor of the journal from 2002 to 2005 and a longtime member of its editorial review board. Along with being known as an exceptional optometric educator, administrator and contact lens clinician and researcher, he was a beloved mentor of young writers.

A committee of the journal's editorial review board selects the winner of the award. The judges rate all the research articles that appeared in the journal in the previous two years. Writing excellence is judged on significance of the topic chosen, quality of the article and potential impact. Authors of the winning paper receive a cash award.

Directions in Optometric Education

In the previous Think Tank, Ken Seger, OD, MSc, FAAO, and Michael J. Giese, OD, PhD, wrote about what they consider to be some of the most important questions facing optometric education.[1] What kind of faculty members are best-suited to meet the needs of an ever-changing profession? From where should the schools and colleges get these faculty members? Whose responsibility is it to train faculty for the future? What makes a good composite faculty? Would it be beneficial to expand the definition of vision science to include areas such as molecular biology, microbiology, pharmacology, immunology or any other "ology" relevant to the profession? Do the schools and colleges need faculty members with advanced degrees?

Optometric Educators Respond

Jamie Althoff, OD
Assistant Professor
Nova Southeastern University
College of Optometry

First, I am not convinced that an optometry school's curriculum should contain more emphasis in areas that are peripherally related to optometry. Undoubtedly, anyone who works in health care will benefit from more knowledge of microbiology, immunology, psychology, etc. However, it is not feasible for all healthcare professionals to have in-depth knowledge of every healthcare subject, which is precisely why we have separate professions and even specializations within these professions. It may be more feasible to let our optometry students focus on subjects that are closely related to the visual system, and give them enough knowledge of other fields so they know when and from where to seek more information. Perhaps a deeper study of many of these "ologies" belongs not in a standard optometry curriculum, but rather afterward, when the optometrist begins to develop a more specific area of interest.

Second, I can offer my personal perspective as a faculty member who was hired as a "newly minted residency-trained OD" less than five years ago. I recently began teaching Geometric and Physical Optics lectures and labs. Although I do not hold an advanced degree in optics, I do feel that my residency training and strong interest in the subject have been sufficient in allowing me to teach effectively. Also, the fact that I am a practicing optometrist allows me to emphasize clinically relevant concepts with credible and practical examples. I have begun coursework toward an advanced degree; however, it is not because I think it is necessary for teaching the class successfully. Rather, working toward another degree simply goes hand-in-hand with my strong interest in and enthusiasm for optics. In other words, I believe it is the enthusiasm that matters, not necessarily the degree.

As my research interests begin to take shape, I do look to our non-OD PhD faculty for inspiration and support. While I can say the same regarding many other senior faculty members without advanced degrees, I do think that PhDs are good for the program because they provide depth and expertise in certain subjects and can help less senior faculty who are interested in further study or research. I would not expect that all PhDs at optometry colleges would also be ODs because, again, specializing in one area might come at the cost of an in-depth knowledge of another area, in this case optometry.

I believe that in order for this system of hiring faculty directly out of residency to produce a "well-educated clinical professorate," we need to look for evidence of certain traits in potential faculty. Some that come to mind are an innate desire to always improve and move forward, a curious nature, a tendency to become stimulated in response to challenges, and an enjoyment of contributing to the success of others. If we hire faculty with traits such as these and help them to do what they are most interested in, I would expect a natural and gradual progression from newly minted, to relatively experienced, to mentor.

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Send Us Your Comments

Do you have any thoughts or insights related to the issues in optometric education presented here? Send your comments to Dr. Aurora Denial at deniala@neco.edu, and we will print them in the next edition of the journal.

Open Access Publishing: Opportunities and Challenges

James Kundart OD, MEd, FAAO

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There has been something of a revolution happening in peer-reviewed publishing. Traditional subscription-based journals in their printed form are no longer the only avenue for making a lasting contribution to the literature. Instead, optometric educators, clinicians, vision scientists and other healthcare practitioners – even our students -- have an increasing number of opportunities to publish their work in an open access forum. What is open access? Simply stated, open access is the immediate, online, no-cost availability of scholarly articles, which unlocks them for everyone to use. **(Figure 1)**

The use of open access has been increasing exponentially, as can be seen in **Figure 2**. One of the success stories in open access is *Optometry & Visual Performance*, which evolved from two U.S. print publications, the *Journal of Behavioral Optometry and Optometry & Vision Development*. *Optometric Education* is also an example of a successful open-access journal. Both *Optometry & Visual Performance* and *Optometric Education* are categorized as "gold" open access publishing, which means they are immediately available on their publishers' Web sites.

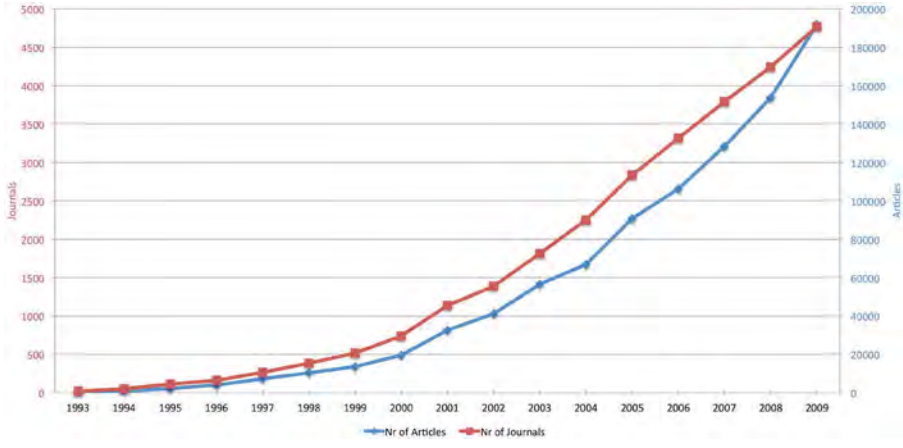
Open access should not be confused with Creative Commons licensing. While open access is the no-cost sharing of scholarly information, the copyright of these manuscripts is owned by the journal itself. Creative Commons licensing is "devoted to expanding the range of creative works available for others to build upon legally and to share." (Wikipedia) Optometric educators may choose to apply this to self-published works, such as a podcast of their lectures. Stipulations can be included to protect against these works being altered or sold. For example, I use the Creative Commons, non-commercial, no-derivatives license when I upload a video podcast to iTunes University on a public channel, like those you'll see here with a guest login: www.pacificu.edu/itunesu.

The Rise of Open Access

The availability of desktop publishing methods and widespread access to high-speed Internet have made the movement toward open access possible. The shift has also been fueled by the increasing cost of institutional subscriptions to print journals, which has rapidly outpaced the rate of inflation.

Figure 1
The open lock symbol, created by the Public Library of Science (PLOS), has come to represent the open access concept.

Figure 2
Development of Open Access, 1993-2009



(Source: http://en.wikipedia.org/wiki/Open_Access)

Institutional subscriptions often cost at least $1,000 per year and sometimes in excess of $10,000. Publishers sometimes bundle electronic access to their journal titles, but they typically costs many times the print subscription. It works much like cable television packages. Subscribers may desire access to only a few channels (i.e., journals) but must purchase all of them as a bundle.

The difference, besides orders of magnitude in the annual price, is that unlike TV, the content of journals was produced by the subscribers themselves. Individual non-subscribers to traditional print journals can usually access articles a la carte. However, as all online researchers know, a "paywall" often blocks online access to articles beyond their abstracts. The paywalls can be high. They are typically at least $25 per article, which must be paid before the article is read. If the article turns out to be not what the reader was looking for, sorry, there are no returns. These rising costs, for both institutions and individuals, are creating a crisis in affordable access to knowledge.

Similarities and Differences Between Open Access and Traditional Publication

In addition to the cost of access and availability of knowledge, the issue of traditional print subscriptions vs. open access involves other considerations. The peer-review process, which provides crucial feedback for strengthening the manuscripts that are fit for publication and rejecting those that are not, is available in both open access and traditional print journals. This keeps the quality of the journals high and provides readers with an impressive array of research and educational and clinical knowledge to put into practice.

Another similarity of both publication models is that authors sign away rights to their work, often for at least a year from publication, when the value of the new knowledge is highest. This may be a fair trade-off for up-and-coming researchers seeking to add to their professional credentials. It also helps the journals to retain their value. In addition, some researchers, including optometric educators seeking tenure and promotion, maintain that publishing in a reputable scientific journal is vital to advancing the academic career.

Note that there are some open-access repositories that are not peer-reviewed, and allow for very rapid publication. While excellent for rapid dissemination of emerging knowledge, this non-reviewed publication model raises the question of whether it carries the same intellectual gravitas as peer-reviewed periodicals. Journals that transition from traditional print to open access, like *Optometric Education* and *Optometry & Visual Performance*, are peer reviewed the same way as always. In fact, the latter journal publishes simultaneously online and on paper.

Open access does provide some significant advantages in accessibility. A 2008 study revealed that mental health professionals are about twice as likely to read and act on evidence in the literature when it is made available under open access.[1] In the same year, a paper in the British Medical Journal noted that open-access publications received 89% more full-text downloads, 42% more PDF downloads and 23% more unique visitors.[2] They also carried an advantage in number of citations, but it only lasted for the first 12 months after publication. After that time period, citations were similar to those within the traditional publication model. Keep in mind that one year is the typical blackout period for a subscription-based publication to have exclusive rights to a manuscript.

Certainly, online publishing provides advantages in regard to the environment, portability, color images and video and swift correction of errors. A potential benefit to researchers is that more people can access their work. It is not difficult to see the potential advantages for optometric educators and students as well.

Educators are acutely aware that optometry is a rapidly-evolving discipline and that courses and clinical knowledge must be kept up-to-date. Constant changes in health care make a static lecture that changes little from year to year of diminishing value to students. Aging books and other monographs, while very worthwhile for foundational knowledge, cannot keep up with the rapid changes. We do have an enviable level of access to e-journals and databases through our excellent vision science libraries, but the traditional journal publication model is slow for the digital age. It takes weeks or months for a manuscript to be revised to pass peer review and reach the public. While quality research and writing take time, it seems increasingly incongruent with the 21st century to wait so long for publication of journals, particularly for people with limited access to the knowledge they contain. Also, negative results, however valuable, are generally less likely than positive results to be published, even if many are not repeatable. The hope is that the discovery of new knowledge will happen faster under the open-access model.

Students, who are often unable to afford paying for access, gain great advantage when information is available freely. It enables them to read complete publications for themselves, which helps them to maintain the evidence basis for what they are being taught. They can even contribute to the knowledge pool easier under this model. A related benefit is that misuse of abstract-only references is less likely. Overall, the open-access model can assist healthcare education in becoming less eminence-based and more evidence-based, as the knowledge base is easier for all to find and peruse.

Even with all its potential benefits, open access has not been immune to criticism. For example, when gold open access to content is provided directly from a publisher's Web site, everyone with an Internet connection can read and cite that content. However, this does not solve the problem of authors being required to release the rights to their intellectual property so that everyone else — including their own institutions — must pay to access it. This is where "green" open access comes in.

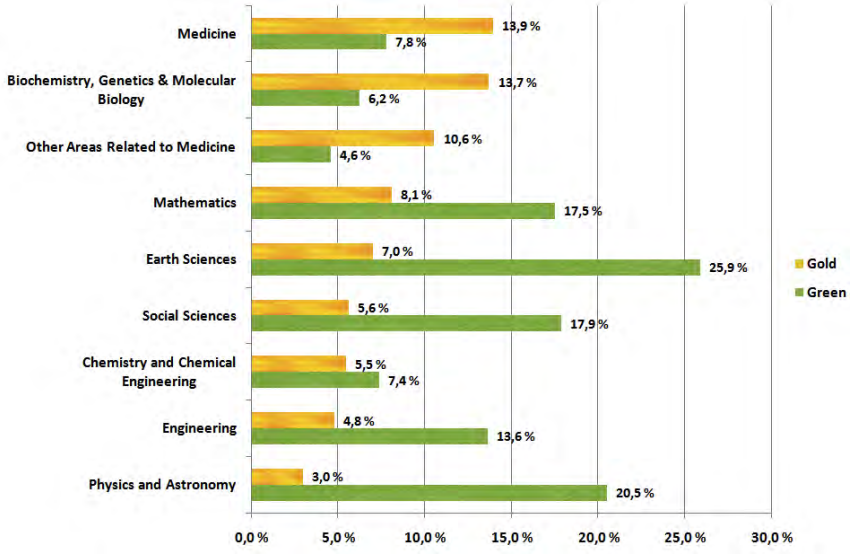
Green open access often takes the form of an institutional repository through the library of a school, college or university. For instance, at Pacific University we make use of "CommonKnowledge" to place the manuscripts written by our faculty and students into the sea of knowledge. With the slogan "Common Access, Uncommon Knowledge," this repository is crawled by Google, and is thus easily searchable by everyone. Like other institutional repositories, it can also be searched directly and freely accessed at http://commons.pacificu.edu. The papers in this repository are clearly marked as to which are peer-reviewed and which are not, although sometimes CommonKnowledge is the

first stop for a new manuscript on its way to such a review. In addition to access, the green approach may help to prevent the idea loss that concerns some authors, particularly those whose manuscripts have been rejected by masked peer review. The increasing use of both gold and green open access by discipline is illustrated in **Figure 3**.

An argument that has been made against open access is that it shifts the burden of payment from subscribers to authors. Indeed, some open-access journals do charge authors a fee to publish. This raises obvious conflicts of interest, especially with regard to access by less affluent authors. However, it does recognize the financial realities that publishing without income from subscribers, or advertisers, becomes a labor of love for the publishers. I know this from my personal experience editing the open-access journal *Health and Interprofessional Practice* (http://commons.pacificu.edu/hip/).

A more equitable model may be to charge to receive peer review. In this model, the peer reviewers are paid for the work that many do as volunteers, in order to better their professions and themselves. To address the objection that authors from less-affluent areas might have less access, some have suggested that the funds libraries would save from the current subscription model could help fund gold open access peer-review fees. Others have strongly objected to this shift, believing that paying for gold open access simply delays the inevitable switch to the more sustainable green open access.[3]

Figure 3
Gold and Green Open Access by Discipline in 2009



(Source: http://en.wikipedia.org/wiki/Open_Access)

The Future is Here

While subscription-based online (gold open access) and institutional-based repository (green open access) will likely co-exist into the foreseeable future, both models are the future of knowledge dissemination. Issues at the center of this transition include financial sustainability, peer review, and intellectual property rights. But it is access to information by our patients, students and peers that ultimately make open access a powerful publication model that optometric educators cannot ignore.

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⭐ 2013 Educational Starter Grants ⭐

The Starter Grants for Educational Research, which are offered by the Association of Schools and Colleges of Optometry (ASCO) and funded by Vistakon, division of Johnson & Johnson Vision Care, Inc., have been awarded since 2011. Each year, ASCO has received an increasing number of grant proposals. This year, 18 grant proposals representing 11 optometric institutions were submitted. The expanding response to the grant program indicates to me an exciting interest in educational research among optometric faculty, who are committed to improving teaching and learning and moving the profession forward. I applaud all faculty who submitted proposals this year. Going forward, I will work to increase grant funding to better support and acknowledge the hard work and interests of optometric faculty.

Congratulations to the recipients of the 2013 Starter Grants for Educational Research:

- Dr. Lawrence Stark, Southern California College of Optometry at Marshall B. Ketchum University (Communicating Educational Objectives in an Optometry Course)
- Drs. Meredith Whiteside, Dennis Fong and Robert DiMartino, University of California - Berkeley School of Optometry (Getting Ready for ObamaCare: Test of a Blended Method for Teaching Medical Coding)
- Drs. Robert DiMartino and Pia Hoenig, University of California - Berkeley School of Optometry (Flipping the Classroom - Using the Internet for Content and Classroom Contact Time for Application)
- Dr. Lorne Yudcovitch, Pacific University College of Optometry (Case-Based Student Performance: Socratic Method vs. Passive Presentation).

— Aurora Denial, OD, FAAO, Editor, *Optometric Education*

Predictors of Academic Success for Students at the Michigan College of Optometry

Robert S. Buckingham, OD, PhD
Sara R. Bush, OD

Abstract

Optometry school admission committees must choose students based on their predictions of the applicants' success. This study evaluates the predictive value of the Optometry Centralized Application Service (OptomCAS) variables. Each undergraduate course taken by students entering the Michigan College of Optometry at Ferris State University was categorized according to the OptomCAS variables. Linear regression analysis found that the Optometry Admission Test academic average and reading comprehension as well as other undergraduate GPAs are the best predictors for academic success. No academic variables could predict graduation. This study provides optometry admission committees additional tools for improving their selection process.

Key Words: *optometric education, graduation, academic achievement*

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Background

Optometry school admissions are very competitive. With more applicants than available slots,[1,2] the Michigan College of Optometry (MCO) admissions committee members must choose, from a myriad of well qualified applicants, those students who they feel will be successful graduates. However, no research has been published analyzing MCO applicants. In addition, very little research has been published on the predictors of academic success in optometry school as it relates to the Optometry Centralized Application Service (OptomCAS) variables.[3,4] OptomCAS is an application service that all students must use to apply to optometry schools in the United States. The purpose of this study is to determine at MCO whether there is a subset of OptomCAS variables that significantly predicts students' grade point averages (GPAs) for each year of optometry school, as well as graduation from MCO.

Optometry schools decided to use OptomCAS for school year 2009-2010 to get a better understanding of the number of applicants and to streamline the application process. All applicants to optometry schools in the United States must apply using this centralized Web-based system in which they are able to use one application to apply to several schools and colleges of optometry. The database includes each applicant's demographic information, recommendation letters, extracurricular activities, colleges and universities that they attend with course history, work/professional experience, individual essay and awards/honors. It then separates this information into a series of variables to allow comparison between applicants based on the GPAs for different types of course work, GPAs for different years of schooling, and Optometry Admission Test (OAT) score breakdown.[5]

The OAT is a computerized standardized test that is required for application to U.S. optometry schools. It includes sections on biology, general chemistry, organic chemistry, reading comprehension, physics and quantitative reasoning. Each section is scored individually as well as averaged into an academic average of all sections. The raw scores are converted to a standard score that ranges

from 200-400 with an average of 300.[6]

To select the appropriate students for admission into an optometry school, admittance committees consider a number of selection criteria such as the OptomCAS variables including undergraduate cumulative GPAs and undergraduate science GPAs, as well as OAT scores.[3,4] For all students entering optometry school in the United States in 2009, the mean GPA was 3.41 on a 4.0 scale. In addition, the OAT academic average score was 334.[7] Because the majority of these students have high GPAs and high OAT scores, the selection committees must choose between applicants who appear very similar.[4]

Since the 2010-2011 cycle, OptomCAS provides optometry schools with 38 different GPA variables.[5] The GPA variables range from freshman to senior cumulative science, non-science, and total GPAs. In addition to the previous, the science, non-science, and total GPA variables include post-baccalaureate cumulative, undergraduate cumulative, graduate cumulative and overall cumulative science, non-science, and total GPAs. Also, included in the GPA variables are the biology/life science GPAs, inorganic chemistry GPAs, organic chemistry GPAs, biochemistry GPAs, physics GPAs, biology/chemistry/physics total GPAs, math GPAs, psychology GPAs, English GPAs, other science GPAs, and other general GPAs. In addition, OptomCAS provides the eight OAT variables: quantitative reasoning, reading comprehension, biology, general chemistry, organic chemistry, physics, total science, and academic average scores.

Even though OptomCAS provides significant information on each applicant, selecting the wrong person can lead to attrition of that student from the program. Attrition has a negative impact not only on the individual but also on the school. Students who enter but do not graduate are encumbered with a large debt without any meaningful skill to pay off that debt.[8,9] As for the schools, revenue from tuition and fees that they would be taking in from the now disenrolled students is lost. Besides the financial loss, there is a significant emotional and psychological toll for the disenrolled students.[8,10,11]

Previous studies in the health profession schools demonstrate that schools have various predictors of academic achievement. Some of the more common predictor variables include pre-admission science GPAs, pre-admission cumulative GPAs, and standardized entrance tests.[10-21]

A retrospective study at the University of Missouri-St. Louis College of Optometry (UMSL) examined the predictors of academic success of optometry students from 1984 through 1992. The study discovered that a grouping of the undergraduate cumulative GPAs, the OCAT (Optometry College Admission Test, the predecessor to the OAT) reading test score, the OCAT biology score, and the personal interview were the best predictors of GPAs at UMSL.[3]

Exploring further into the personal interviews, Spafford investigated the types of interviews performed during the admissions process at optometry schools. In this study, the optometry schools ranked the importance of certain variables in the decision process for admitting students. The schools ranked the undergraduate GPAs as the highest ranked admittance variable followed by the OAT scores, interview and references.[22]

Investigating OAT scores, Kramer and Johnston examined the relationship between OAT scores, undergraduate GPAs and first- and second-year GPAs in seven optometry schools. The study revealed that the best predictor of optometry school GPA was a combination of undergraduate GPAs and OAT scores.[23]

In 2007, researchers at Pacific University College of Optometry evaluated 175 student records for academic success. This study found that the 1) undergraduate science GPAs, 2) GPAs of the last 45 undergraduate credits, 3) undergraduate cumulative GPAs, 4) OAT academic average score, 5) OAT quantitative reasoning score, 6) OAT general chemistry score, 7) OAT organic chemistry score, and 8) OAT total science score demonstrated a statistically significant difference between students who failed a course and students who did not fail a course.[4]

In the admissions process in the past, MCO used the following variables for the selection process: the OAT academic average score, the overall undergraduate GPA, and the overall prerequisite GPA as well as knowledge of the profession, optometric experience, employment, extracurricular activities, personal essay, letters of recommendation, and honors/awards. With the advent of OptomCAS, no research has been accomplished on the predictors of success as it relates to the OptomCAS variables. Therefore, the authors evaluated the predictors of academic success at MCO using the OptomCAS variables. To this end, the purpose of this study is to determine whether there is a subset of OptomCAS variables that significantly predicts the students' GPAs for each year at MCO, as well as graduation from MCO. A study of this nature provides the MCO optometry admissions committee the tools to make wiser decisions when enrolling students.

There are three research questions. The first research question evaluated the ability of the OptomCAS variables to predict first-year, second-year, third-year and fourth-year cumulative GPAs at MCO. The second research question assessed the ability of the variables to predict graduation from MCO. The third research question evaluated whether the OAT data provide meaningful information above and beyond the GPA data in predicting end of the year GPA and graduation from MCO. This provides information on the value of a standardized entrance test.

Methods

The research design employed in this study was non-experimental, ex post facto because the data variables were evaluated after their normal occurrence.[24] The data were collected from archival data of student records from MCO. The population for this study included all students who started optometry school at MCO from 1995 through 2004 and who graduated or should have graduated from MCO in the years 1999 through 2008. During this time period, the entering class size ranged from 32 to 34 students. These years were selected because the OAT scores were recalibrated in May 2009. In addition, the curriculum at MCO underwent a major change beginning with the Class of 2009. Students who were still enrolled in the optometry

program were not included nor were students who were disenrolled due to non-academic reasons.

Of the nearly 3,000 applicants from 1995 through 2004, 327 students were admitted to MCO. Of those students, 4 were disenrolled due to non-academic issues and another was eliminated due to a lack of the normal prerequisites. For MCO, the normal prerequisites were 1) one year of general biology with lab, 2) one year of general chemistry with lab, 3) one year of organic chemistry with lab, 4) one year of physics with lab, 5) one year of English, 6) a microbiology course with lab, 7) a calculus course, 8) a statistics course, 9) an introductory psychology course, and 10) a speech/communications course.

The 322 students in the study took a total of 13,203 courses before entering MCO. Based on the classification in the students' transcripts, all 13,203 courses were categorized into freshman, sophomore, junior, senior, post baccalaureate, or graduate courses. In addition, the 13,203 courses were classified into biological/life science, inorganic chemistry, organic chemistry, biochemistry, physics, math, English, psychology, other science, or other general courses. The previous two years of OptomCAS data entry was used as a guide in the classification of the courses.

GPAs were computed for each student for each of the above OptomCAS variables. The GPAs were computed by summing the points earned for each course and dividing this number by the credit hours attempted. To ensure equity between educational institutions, if the college was on a quarter hour system, the total number of credit hours was converted from quarter hours to semester hours when appropriate. For example, a 3-credit course in quarter hours is equivalent to a 2-credit course in semester hours.

SPSS for Windows was employed to analyze the data. When data were found to be missing, multiple imputation was employed.[25-30] The authors employed descriptive and inferential statistics to portray and analyze the data on the variables.[24,27,31-34] The probability level was set at .05 for rejecting the null hypotheses.

The dependent variables were graduation, first-year cumulative GPA, second-year cumulative GPA, third-year cumulative GPA, and fourth-year cumulative GPA. The dependent variable, graduation, was nominal, categorical and was coded as graduate or non-graduate.

For research question 1, we used linear regression analysis for evaluation of the GPAs. To minimize collinearity, the predictor variables were narrowed down using the forward stepwise regression model. The forward stepwise regression adds predictor variables with the highest partial correlation as long as the variable is statistically significant. It continues to add predictor variables based on the partial correlation until none of the predictor variables is statistically significant.[32,35-39] For research question 2, binary logistic regression tests were used to predict graduates vs. non-graduates based on the independent variables. For the logistic regression, a forward elimination likelihood ratio regression model was employed to produce the odds ratio. The odds ratio is defined as the increase in the dependent variable for a unit increase in the independent variable. The forward elimination uses the likelihood-ratio test to enter or remove variables from the model.[33-36,40,41] For research question 3, we employed both linear regression and binary logistic regression analyses. In this scenario, the data were partitioned into two segments. One segment was the coursework GPAs and the other segment was the OAT data. A stepwise regression was then performed on the coursework GPAs and not on the OAT information. Next, a two-block enter method linear regression was done with the first block being the variables identified in the previous regression equation and the second block being the OAT academic average score. We then compared the change in the adjusted R square values and the change in the Nagelkerke R square values for the first block compared to the second block. This provided the effect of adding the OAT variables into the predictor model.

Results

From 1995 through 2004, there were 327 students who entered MCO. Of those students, 4 were disenrolled due to non-academic issues and another was eliminated due to a lack of normal prerequisites. Therefore, the total number of students in this study was 322. Of the 322 students, 12 students did not graduate and 310 graduated.

Of the 322 students, no students had any graduate classes prior to entering MCO. Thus, the 3 graduate GPA variables and the 3 overall GPA variables (which included the graduate GPAs) were eliminated from analysis.

Further analysis revealed that very few students had post baccalaureate GPAs. In addition, the listwise analysis revealed that only three students had data for each of the independent variables. A listwise analysis excludes an entire record if any single value pertaining to that record is missing, significantly reducing our eligible sample size. Due to the low frequency, the 3 post baccalaureate GPA variables were eliminated from the analysis. This left 37 independent variables for analysis.

Research question 1

Research question 1 asks to what extent the independent variables are predictive in determining the GPAs for each year of optometry school. We evaluated if we should use a stepwise or backward data entry method for the linear regression. Due to the excessive multicollinearity with the backward stepwise model, we employed the stepwise model.[38,39] In addition, missing values were evaluated in the data using the multiple imputation method.[42-45] After utilizing multiple imputation, the authors performed some exploratory forward and backward stepwise linear regression on the imputed data and the original data. The authors then compared the adjusted R square values for the imputed data vs. the original data. The authors found that the original data had higher adjusted R square values than the multiple imputation data. The lower adjusted R square values of the imputed data may be due to variance induced by the estimations employed when performing multiple imputation. Based on this information, the authors decided to use only the original data.

Next, the authors evaluated whether a forward stepwise linear regression or a backward stepwise linear regression would be a better predictor model of

the cumulative optometry GPAs. To accomplish this, the authors evaluated the multi-collinearity of the two models. Of the two models, the forward stepwise model had significantly less multi-collinearity than the backward stepwise model. Due to the excessive multi-collinearity with the backward stepwise model, the authors employed the forward stepwise model.

For the linear regression using the forward stepwise method, **Table 1** compares the variables of the regression equation for the original data for the first, second, third, and fourth-year cumulative GPAs. For the original data, the regression equation is First Year GPA = -0.131 + [0.009 (OAT Academic Average)] + [0.166 (GPA Math)]. For the second-year data, the regression equation is Second Year GPA = -0.705 + [0.008 (OAT Academic Average)] + [0.225 (GPA Biology)] + [0.410 (GPA Undergraduate Non-Science)] + [-0.187 (GPA Sophomore Non-Science)]. For the third-year data, the forward stepwise linear regression equation is Third Year Grade Point Average = -0.134 + [0.006 (OAT Academic Average)] + [(0.314 (GPA Biology)] + [0.577 (GPA Undergraduate Non-Science)] + [-0.258 (GPA Sophomore Total)] + [-0.172 (GPA Junior Non-Science)]. For the fourth-year data, the regression equation is Fourth Year GPA = 0.270 + [.005 (OAT Academic Average)] + [0.336 (GPA Biology)] + [0.002 (OAT Reading Comprehension)].

Table 1 reveals that the OAT academic average is a significant predictor for academic performance for all four years and the undergraduate biology GPA is a significant predictor for second to fourth years in optometry school. In addition, undergraduate math GPA is related to academic success in first-year optometry, while undergraduate non-science GPA is related to second- and third-year optometry school GPA. The linear regression equations also include undergraduate sophomore non-science GPA for predicting second-year optometry school GPA, undergraduate sophomore total GPA for predicting third-year optometry school GPA, undergraduate junior non-science GPA for predicting third-year optometry school GPA, and the OAT reading comprehension score for predicting fourth-year optometry school GPA.

Table 1
Comparison of Regression Variables and Coefficients for GPAs

Variables with Coefficients	1st Year	2nd Year	3rd Year	4th Year
(Constant)	-.131	-.705	-.134	.270
OAT Academic Average Score	.009	.008	.006	.005
Math GPA	.166			
Biology GPA		.225	.314	.336
UG Non-Science GPA		.410	.577	
Sophomore Non-Science GPA		-.187		
Sophomore Total GPA			-.258	
Junior Non-Science GPA			-.172	
OAT Reading Comprehension Score				.002

Table 2
Model Comparison of Cumulative GPA Data

Year Data	R	R Square	Adjusted R Square	Std. Error of the Estimate
First Year	.585	.342	.329	.33653
Second Year	.721	.520	.501	.26011
Third Year	.729	.531	.507	.23179
Fourth Year	.736	.541	.528	.22371

Table 2 shows a comparison of the original data adjusted R square value for the dependent variables. The adjusted R square value increases as the student advances from first year to fourth year. By the time the student is in the fourth year of optometry school, the linear regression equation accounts for about 52.8% of the variance in the cumulative GPAs. Thus for the regression models, it is harder to predict first-year optometry school GPA than the subsequent second- through fourth-year optometry school GPAs.

Research question 2

Research question 2 asks to what extent the independent variables are predictive in determining those students who are academically disenrolled (non-graduate) and students who graduate. The analysis revealed that 109 records were included in the analysis and 213 records were excluded from the analysis. The Nagelkerke R square was .177. The Nagelkerke R square is a pseudo R square and is not equivalent to the R square in linear regression. Nagelkerke R square is used to compare models to see which one explains more of the variance.[33,36]

For the logistic regression, only one variable, sophomore science GPA, was statistically significant. The logistic regression equation was the log-odds of Graduation = -3.267 + [2.37 (sophomore science GPA)]. When applying a 50% cutoff for the 315 students with a sophomore science GPA, the equation predicts that all students will graduate. Using this 50% cut off, the logistic regression equation sensitivity is 96.3% and the specificity is 0%. This reveals that the logistic regression equation is a poor predictor of selecting individuals who will not graduate from MCO.

Research question 3

The third area the researchers investigated related to the importance of the OAT scores in determining graduation of students from the optometry college (graduate vs. non-graduate) and end of

the year GPAs after each year of school. For first- through fourth-year GPAs, a linear regression was performed on the data which did not contain the OAT information. In the second step in the analysis, a two-block enter method linear regression was performed with the first block being the variables identified in the previous regression equations and the second block being the OAT academic average score. This provided the effect of adding the OAT variables into the predictor model.

Table 3 compares the adjusted R square for the block one data without the OAT information and the block two data where the OAT academic average score was added. For the first, second, third and fourth-year GPAs, the data with the OAT academic average score information have a higher adjusted R square value. In fact, the OAT academic average score accounts for about 10% of the variance in the dependent variables. In addition, **Table 4** reveals that the F change is statistically significant for all of the cumulative GPAs, which indicates that there is a statistically significant difference in the R value and the adjusted R square value when adding the OAT academic average score.[46]

Because the OAT data account for a statistically significant amount of additional variance and because the F change is statistically significant by adding the OAT, the OAT academic average score is important in the predictability of the first, second, third and fourth-year optometry cumulative GPA.

For graduation vs. non-graduation, binary logistic regression revealed that the sophomore science GPA was the only variable in the logistic regression. With adding the OAT academic average score to the logistic regression equation, the Nagelkerke R square increased from 0.133 to 0.154. This means that by adding the OAT academic average score to the model, there was more variance explained than using the data with the sophomore science GPA only. Sophomore science GPAs were found to be statistically significant with a p value of .002, but the OAT academic average score was not statistically significant with a p value of .176. This means that OAT academic average score should be removed from the logistic regression equation and the sophomore science GPA should remain in the equation.

Table 3
Comparison of Dependent Variable Adjusted R Square

Dependent Variable	Non-OAT Data Adjusted R Square	OAT Data Adjusted R Square
First Year	.274	.358
Second Year	.358	.459
Third Year	.354	.453
Fourth Year	.398	.498

Table 4
Model Summary and Change Statistics for Cumulative GPA

Year	Model	R Square	Adjusted R Square	Change Statistics				
				R Square Change	F Change	df1	df2	Sig. F Change
Cum. First Year GPA	1	0.281	0.274	0.281	43.524	2	223	0.000
	2	0.366	0.358	0.086	29.977	1	222	0.000
Cum. Second Year GPA	1	0.364	0.358	0.364	62.029	2	217	0.000
	2	0.467	0.459	0.103	41.621	1	216	0.000
Cum. Third Year GPA	1	0.36	0.354	0.360	60.584	2	215	0.000
	2	0.461	0.453	0.100	39.874	1	214	0.000
Cum. Fourth Year GPA	1	0.403	0.398	0.403	72.367	2	214	0.000
	2	0.505	0.498	0.102	43.872	1	213	0.000

Discussion

The purpose of this study was to evaluate the ability of the OptomCAS variables to predict the GPA and/or graduation of students in MCO. Research question 1 asked to what extent the independent variables are predictive in determining end of the year GPAs for first year, second year, third year and fourth-year optometry students. **Table 2** compared the original data adjusted R square value for the dependent variables, displaying an increased adjusted R square from first-year GPAs to fourth-year GPAs. Looking at the predicted fourth-year GPAs, 52.8% of the variation in the GPA is accounted for by the variables in the regression equation. This adjusted R square is very high, meaning the variables in **Table 1** are excellent predictors of first-year through fourth-year optometry GPAs.

Looking at the variables and the coefficients of those variables in **Table 2**, the OAT academic average score is important in predicting all cumulative GPAs; however, the coefficients reveal that the importance of the OAT decreases from first-year GPAs (.009) to fourth-year GPAs (.005). The math GPAs are a good predictor of success in the first year, whereas biology GPAs are a good predictor in the second through fourth years of optometry school. This is reasonable because optics, which employs intensive math skills, is taught in the first year of optometry school at MCO. In the second through fourth year of optometry school, general biology skills are more important as these years are more focused on pathology, pharmacology, ocular disease and other science courses. Beyond this, the pre-optometry non-science GPAs, which include English, math, other general, and psychology GPAs, as well as the OAT reading comprehension scores, are predictor variables. Perhaps this relates to the graduate level reading material en-

countered during these years. In short, the better the student comprehends information while reading, the higher GPA the student will achieve.

When comparing this study to other similar research studies, this study supported Wingert's findings that undergraduate course GPAs and certain OAT scores are predictors for first- and second-year GPA.[3] This study also supported the findings of Kramer and Johnston that both the undergraduate course GPAs and OAT scores are predictors for first- and second-year GPA.[23] Finally, this study supported the findings of Goodwin that both the undergraduate course GPAs and OAT scores are predictors for first- and second-year GPA.[4]

Research question 2 asked to what extent the independent variables are predictive in determining those students who are academically disenrolled (non-graduate) vs. students who graduate. The logistic regression revealed that only one variable, sophomore science GPA, was found to be statistically significant in being able to differentiate between graduation and non-graduation of students. The 36 other independent variables were found to be not statistically significant in their ability to differentiate between students who graduate and students who do not graduate.

An excellent logistic regression equation should be able to predict the probability that a subject will graduate or not graduate from MCO. Of the 315 students with a sophomore science GPA, the logistic regression equation predicted all would graduate. Using a 50% cut off, the logistic regression equation sensitivity is 96.3% and the specificity is 0%. Therefore, the binary logistic regression equation is a very poor predictor of identifying individuals who will not graduate from MCO. This poor performance of the logistic equation could be caused by the small number of non-graduates in this study. Another possibility for the poor predictability of the logistic regression equation could be due to the fact that the 37 academic-based variables may not be the main cause for disenrollment from optometry school. There may be non-academic issues affecting the students' academic success and these non-academic reasons are causing these students to not graduate. Even though the logistic equation could not predict non-graduation, the results could be accurate. For example, if a student fails due to non-academic issues such as working 40 hours a week or a death in the family, no academic variables would stand out as predictors for non-graduation.

When comparing this study to other similar research studies, this study added to Goodwin's findings that undergraduate science GPA and total science OAT scores are predictors for failing a course.[4] In addition, this study takes the knowledge base one step further by evaluating graduation of optometry students. Most of the other optometry achievement studies evaluated GPA in optometry school.

Research question 3 evaluated the importance of the OAT scores as predictors for academic achievement for students at MCO. In other words, should the standardized OAT be significant to an optometry school's selection process? In the linear regression analysis, improvement was found in the adjusted R square values when adding the OAT academic average score. **Table 3** compares the adjusted R square for the undergraduate course variables without the OAT variables and the adjusted R square for the undergraduate course variables with the OAT academic average score added. For the first, second, third and fourth-year cumulative GPAs, the data with the OAT academic average score information has a higher adjusted R square than the data without the OAT information. In fact, by adding the OAT academic average score, the linear regression equation provides about a 10% increase in explaining the variance in the first, second, third and fourth-year cumulative optometry GPAs. The additional amount of variance explained is statistically significant at $p < 0.001$ level for all equations. Because the OAT data account for a statistically significant amount of additional variance above and beyond those explained by the undergraduate course grade point averages, the OAT academic average score is important in the predictability of the first, second, third and fourth-year optometry cumulative grade point average. As for the graduation vs. non-graduation analysis, the results were exactly the same as the results of research question 2.

When comparing this research question 3 to other similar research studies, this study supported the findings of Kramer and Johnston that both the undergraduate course GPAs and OAT scores are better predictors for first- and second-year GPA than undergraduate course GPAs alone.[23] This study also added to the knowledge base by showing that the OAT scores are valuable in predicting optometry GPA throughout the four years in optometry school.

Delimitations and Limitations

A few factors limit this study. Categorization of each course into the OptomCAS categories was a somewhat subjective process and could have potential researcher bias. In addition, the study was only conducted at MCO. Thus, other schools may not be able to extrapolate the results to their applicants. Further, the independent variables used in this study are those provided by OptomCAS. There may be other unknown variables that could be predictors of first, second, third and fourth-year cumulative GPAs. In addition, course grades for clinical performance at MCO are credit/no credit. These courses are not included in the overall GPAs of the students. Thus, this study does not directly evaluate the clinical performance of the students. Another issue is that faculty members at different institutions may employ different grading criteria, which in turn would affect an applicant's undergraduate GPA. Another limitation of the study was the low number of students who did not graduate from MCO. This low number could skew the results of the logistic regression. Finally, the current process of selecting students may influence the statistical analysis. Results may be skewed because students with low OAT scores and low GPAs are not generally admitted into MCO due to the competitiveness of the admissions process and the challenging nature of the program.

Recommendations for Future Research

In this study, the researchers found that 30% of the data was missing due

to students not having a senior non-science GPA, senior science GPA, and senior total GPA. Historically, approximately 25% of each entering class consists of applicants who do not have a bachelor's degree. A follow-up study should evaluate if the students entering MCO without a bachelor's degree differ from students entering MCO with a bachelor's degree. Looking beyond the OptomCAS variables, there may be other variables that might be indicators of optometry school GPA, such as repeating undergraduate courses, withdrawing from undergraduate courses, failing undergraduate courses, etc. In addition, the number of undergraduate credit hours achieved and possibly the number of undergraduate colleges the individual attended could be evaluated as potential predictors of success in optometry school.

Another possible area of research would be to perform the analysis on recent graduates. The data in this study used OAT scores prior to May 2009. In May 2009, the OAT scores were recalibrated. In addition, by adding another semester of classroom instruction, the curriculum at MCO underwent a major change starting with the Class of 2009. A follow-up study should evaluate the predictors under these new conditions.

Conclusions

Optometry school admissions are very competitive. There are more applicants than there are available seats in optometry schools. The optometry admissions committees must choose, from a myriad of well-qualified applicants, those students whom they feel will be successful graduates. The results of this study found that of the 37 variables reviewed, the OptomCAS variables of 1) OAT academic average score, 2) OAT reading comprehension score, 3) math GPA, 4) biology GPA, 5) undergraduate non-science GPA, 6) sophomore non-science GPA, 7) sophomore total GPA, and 8) junior non-science GPA are predictors of academic achievement at the Michigan College of Optometry. These eight variables explain over 50% of the variance in MCO student GPA. Therefore, when evaluating potential applicants for future academic achievement in optometry schools, admissions committees should give careful consideration to these eight variables.

In addition, this study found that the logistic regression equation involving these academic-based 37 variables is a poor predictor of selecting individuals who will not graduate from MCO. The reason may be the small number of non-graduates in this study, or it may be due to the fact that the 37 academic-based variables may not be the main cause for disenrollment from optometry school. There may be other life or non-academic issues that may be causing these students to not graduate. Future study in this area is warranted. Finally, this research found that both undergraduate course variables and OAT variables combined were better predictors than undergraduate course variables alone, which means that the standardized OAT does add value to the selection process.

The authors recommend that the optometry school admissions committees review the above eight variables for applicability to selection of their applicants. In addition, because the reason students do not graduate from optometry school may be related to non-academic issues, optometry schools should consider gathering information to evaluate the non-academic life issues of their students as well.

Overall, this study increases the current knowledge on optometry school selection criteria variables and the importance of the OptomCAS variables. It also provides optometry admissions committees additional tools for improving their selection process.

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Impact of Interactive Instructional Tools in Gross Anatomy for Optometry Students: a Pilot Study

Patricia C. Sanchez-Diaz, DVM, PhD

Abstract

Background and significance: *Virtual resources have become a popular way to enhance lecture and laboratory instruction; however, there is no experimental data assessing their effectiveness in optometry. This study evaluated the effects of different interactive strategies on student motivation and learning outcomes.*

Methods: *Sixty-five optometry students were assigned to control and intervention groups for the anatomy laboratory. Post-laboratory quizzes and questionnaires were used as assessment tools.*

Results: *Although questionnaires revealed a positive response, no significant differences were found in quiz scores between the intervention and control groups.*

Conclusion: *Interactive and audiovisual instructional resources might increase student motivation in anatomy. This may be beneficial for healthcare programs without cadaver labs.*

Key Words: *optometric education, gross anatomy, interactive instructional tools, audiovisual instructional tools*

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Introduction

A strong foundation in the basic sciences is essential to ensure the achievement of clinical competencies in our future graduates.[1] Clinical anatomy is a challenging discipline in most healthcare programs, including optometry. It requires deep knowledge of anatomical structure, function and their relationships in order to fully understand the clinical correlates. Classical approaches to learning anatomy have emphasized the memorization of lists of descriptive anatomical terms and features, proof of which is the endless and maybe creative catalog of mnemonics commonly used to better retain the information. Different studies have historically aimed to find the perfect strategy for obtaining the best educational outcomes fitting the peculiarities of Malcolm Knowles' adult learning theories.[2,3] Some recent studies support the effectiveness of student motivation and the utilization of interactive and experience-based learning methods (i.e., constructivism) in anatomy courses.[4,5,6,7] However, it seems that there is not a perfect recipe for success in this matter.

New technologies are having a tremendous impact on the way we learn and teach. Computer and/or Web-based resources are gaining popularity as lecture- and laboratory-enhancing tools. In fact, virtual dissections and 3D interactive anatomical models, which aim to provide visualization and a better understanding of the potential clinical implications of anatomical dysfunction, are emerging as convenient supplementary methods, or even substitutes, for the use of cadavers.[5,8,6,7,9]

The purpose of this study was to evaluate the effects of different educational strategies in motivation and in learning outcomes of first-year optometry students. The results of this work suggested that the utilization of supplementary audiovisual resources and virtual 3D models, along with the creation of critical-thinking questions and clinical scenarios, may enhance the laboratory instruction in anatomy by promoting student motivation. The results obtained with this pilot study may allow us to apply similar strategies in more

clinical courses in optometry and possibly in other health sciences programs.

Methods

This study was conducted with approval from the Institutional Review Board Committee of the University of the Incarnate Word (protocol #11-08-005). Invitation letters were sent to the university's 65 first-year optometry students. All 65 students enrolled in the Anatomy and Histology course (fall semester 2011) signed the consent letter, and they all completed the study.

Design overview and instructional tools

Students were assigned to two laboratory groups (control and intervention) based on their last names in alphabetical order. In both groups, laboratory instruction was performed in two-hour laboratory sessions for a period of 13 weeks. Results from post-laboratory quizzes were collected only during the first seven laboratory sessions. During this initial period, laboratory instruction did not include the use of any interactive or audiovisual instructional tools for the control (Tuesday) group. Only traditional methods, e.g., atlases, textbooks and anatomical laboratory models, were used. Instruction for the intervention (Thursday) group was enhanced by the addition of interactive and audiovisual tools, which included iPad applications **(Table 1)**, YouTube videos (related to cadaver dissections, medical procedures or functional anatomy), clinical scenarios and/or the elaboration of critical-thinking questions. In both the control and intervention groups, five to six students sat at each table, and teamwork was strongly encouraged. At the end of the laboratory session, students were asked to take a post-laboratory quiz consisting of applied and clinical questions.

Students tend to share information they consider relevant for their learning. In order to prevent this from affecting the study results, I did the following. 1) The control group for each laboratory session met prior to the intervention group so that students in the intervention group were only able to share the supplemental tools with students in the control group once the control group had already taken the lab quiz. 2) Students in the control group were asked not share quiz questions with students in the intervention group. 3) Students were aware that the grades obtained in these laboratory quizzes did not count toward their course grade. The fact that the control group scored slightly higher on all laboratory quizzes than the intervention group further confirmed that students did not discuss any information relevant to this study.

Data analysis

Averages and distribution of post-laboratory quiz scores were compared between the control and intervention groups. An anonymous laboratory evaluation form comprising a five-point Likert scale questionnaire and three open-ended questions **(Table 2)** was given to the students at the end of the 13th laboratory session to gather their feedback. Data is presented as average plus/minus (±) standard deviation. Linear regression analyses (SPSS predictive analytics software, IBM) were performed to determine statistical differences between group quiz scores. To compensate for potential inherent differences between the control and intervention groups, student demographic (gender, age and ethnicity) and academic (if they had a bachelor's degree, if they had taken a pre-optometry anatomy course and the final grade

Table 1
iPad Applications Used in this Study

1.	Netter's Anatomy Atlas
2.	Gray's Anatomy for Students Flash Cards
3.	Netter's Concise Radiologic Anatomy
4.	Netter's Advanced Head and Neck Flash Cards
5.	Human Body 3d 2
6.	Heart Pro (NOVA Series) - iPad edition by 3D4Medical
7.	Skeletal System Pro II - (NOVA Series) - iPad edition by 3D4Medical
8.	Clemente's Anatomy Flash Cards
9.	Digestive System - iPad edition by 3D4Medical
10.	Brain Pro Nova series
11.	Muscle System Pro II - (NOVA Series)
12.	Nervous System - iPad edition by 3D4Medical
13.	Skeletal 3d Anatomy for iPad

Table 2
Five-Point Likert Scale Questionnaire and Open-Ended Questions

Questionnaire 1: strongly disagree 2: disagree 3: neutral 4: agree 5: strongly agree	
1.	The laboratory learning objectives were met by using Interactive Instructional Tools (IIT)
2.	The use of IIT allowed you a better understanding of important concepts
3.	The use of IIT improved your performance in this course
4.	The IIT offered in this course were user-friendly
5.	The IIT offered in this course were convenient learning methods
6.	The IIT offered in this course were stimulating and engaging learning methods
7.	The IIT offered in this course allowed you to be less dependent on the instructor
8.	The IIT offered in this course resulted in a more efficient utilization of the instruction time
9.	The experience was overall effective for your learning
10.	You would like to use IIT in other courses
Open-ended questions	
1.	From the IIT used in this course, which one did you find most beneficial in your learning?
2.	Which IIT did you like best?
3.	Please provide any suggestions that may improve laboratory instruction

obtained in this anatomy course) information was included as variables in the regression analyses. P<0.05 was used as the cutoff to determine statistical significance.

Results

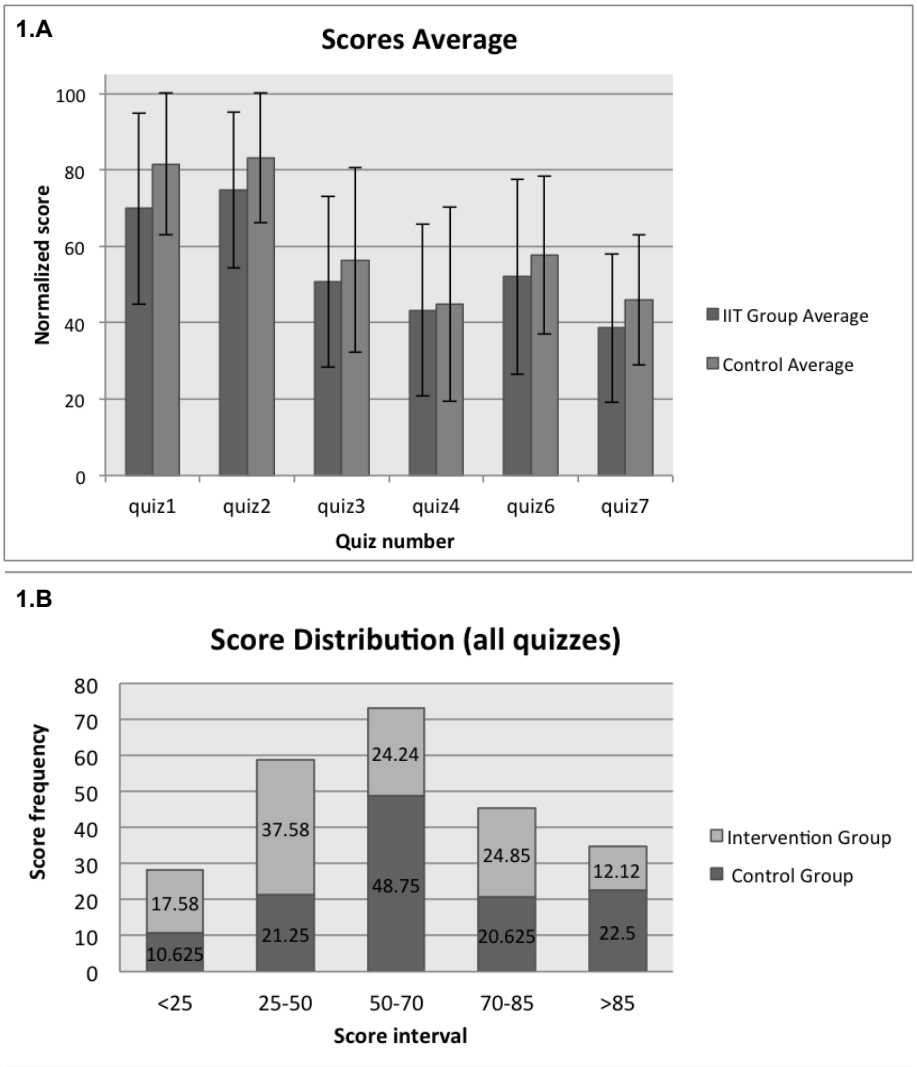
In this study, I evaluated the impact of the incorporation of several supplementary resources in the gross anatomy laboratory. Learning outcomes and student perceptions were evaluated in control and intervention groups as described in the Methods section. Although groups were not randomly generated, no statistical differences were found in course grades between the control and intervention groups — average course grade for the control group was 77.57% vs. 78.42% for the intervention group (p=0.713) — or between any of the other academic or demographic variables included in the regression analyses (data not shown). While the control group seemed to consistently score higher in the quizzes **(Figures 1.A and 1.B)**, no statistically significant differences were found between the control and intervention groups.

Anonymous evaluation questionnaires were collected from 52 of the students (80% return rate) at the end of the semester. At that point, both the control and intervention groups had had access to the same instructional resources for a period of five weeks. The results from the five-point Likert scale questionnaire and from the three open-ended questions **(Figures 2 and 3)** showed that students truly enjoyed the audiovisual and interactive tools. **Figure 2.A** shows the distribution of the student responses in the five Likert categories (strongly

Figure 1

Quiz Grade Average and Distribution in Interactive Instructional Tools (IIT) (intervention) Group and Control Croup

A. Score averages for each independent quiz. Quiz grades for intervention (n=32 students) and control group (n=33 students). Average quiz grades and standard deviations are plotted in the graph for each group. Although the control group seemed to score slightly higher in each quiz, the differences failed to be statistically significant (p values ranging from 0.051 to 0.76). **B.** Score distribution for all quizzes combined. The number of students scoring in each interval is shown in the plot for all six quizzes combined. Quiz number five had to be dropped due to unforeseen circumstances.



disagree, disagree, neutral, agree and strongly agree), and **Figure 2.B** shows the average value on a 1 to 5 scale for each question. Generally, the students felt that these supplementary tools were, over a total of five points, user-friendly (4±0.76; for Q4), convenient (3.98±0.77; for Q5), stimulating and engaging (3.82±0.77; for Q6), effective (3.76±0.79; for Q9) and that they would like to incorporate them in additional courses (4.04±0.88; for Q10). Of note, the lowest score in the five-point Likert questionnaire (3.2±0.95; for Q7) was recorded for the item "the IIT (interactive instructional tools) offered in this course allowed you to be less dependent on the instructor."

In the open-ended questions, students selected dissecting videos as the most effective instructional tool (26 out of 64 responses; 40% of collected responses) and also as the best liked along with iPad applications (22 out of 56 responses for each tool; 39% of collected responses). The results from the open-ended questions are plotted in **Figure 3**. Very interestingly, iPad applications scored lower than the other tools regarding their benefits toward learning (9 out of 64 responses; 14% of collected responses).

Discussion

Interactive learner-centered strategies, such as problem-based approaches, seem to foster essential attributes in health sciences students, including lifelong learning, critical thinking, decision-making and communication and reflective skills.[2,10,4] New computerized and Web-based technologies are becoming popular in teaching and self-directed learning of anatomy. These materials are, most of the time, convenient and easily available to students and thus may provide them with a collection of instructional tools they can access anytime. However, the actual value of these methods in enhancing learning in anatomy compared to cadaver dissections remains controversial.[11,12,13,14,15] In our study, the supplemental tools did not seem to have a significant impact on student learning outcomes. Intriguingly, and although the difference fails to be statistically significant, it seemed that the control group actually scored higher in the post-laboratory quizzes

Figure 2
Results of the Five-Point Likert Questionnaire

A. Distribution of student responses. The plot shows the number of students answering: strongly disagree, disagree, neutral, agree and strongly agree, for each of the 10 questions in the questionnaire. **B.** Average Likert value of student responses. Average Likert values with standard deviations are plotted for each question. The values in the plot were obtained using the following conversion: strongly disagree = 1; disagree = 2; neutral = 3; agree = 4; and strongly agree = 5.

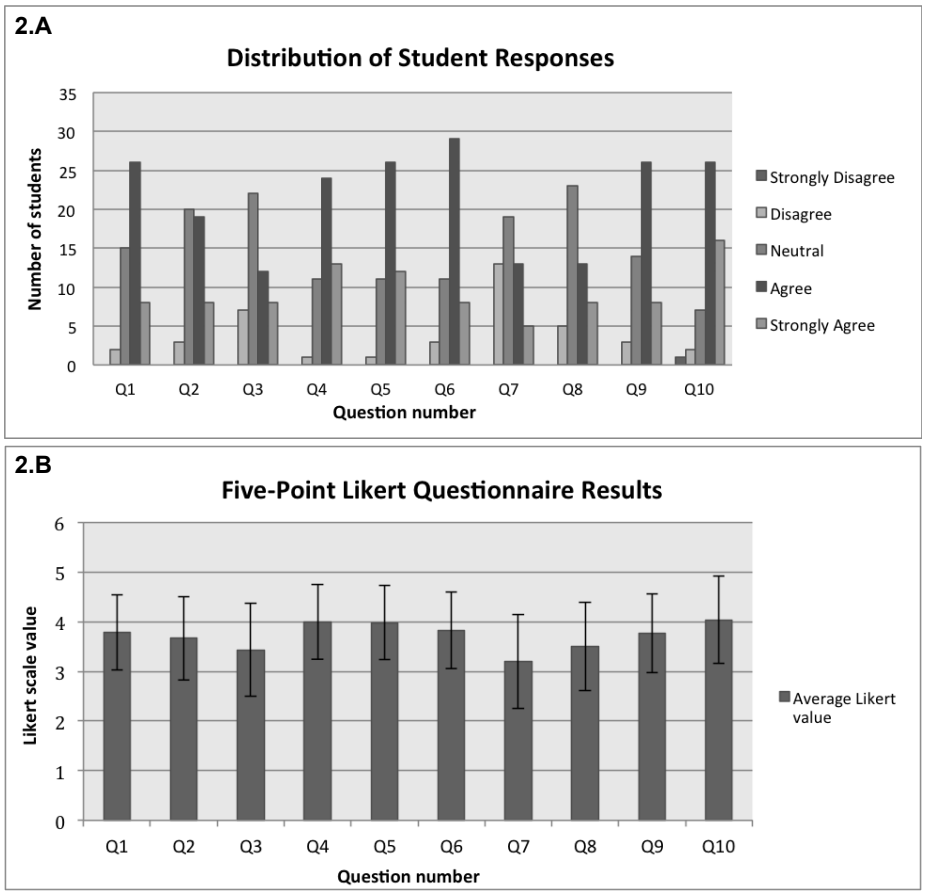
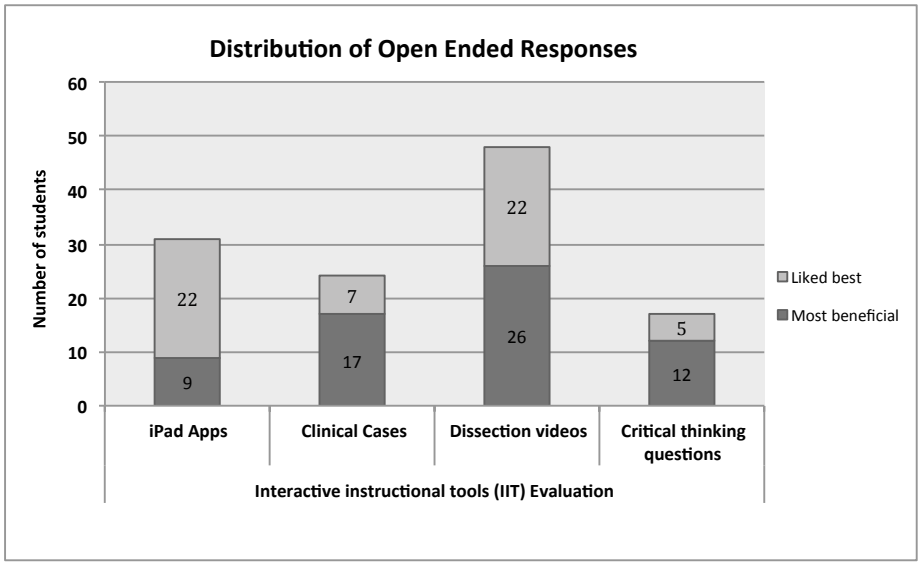


Figure 3
Results of Open Ended Questionnaire

Students were asked to indicate which of the utilized methods they liked best and, in their opinion, which was/were the most beneficial for their learning. From the questionnaires, dissection videos seemed to be the best instructional tool. Students also liked the iPad applications; however, they scored lower than the other tools regarding their benefits toward learning.



than the intervention group (Figures 1.A and 1.B). A possible explanation for this may be the time students invested to become proficient with the use of the iPad and its applications. If this were the case, students in the control group might have been more cost-efficient at least in the short term by just using their atlases and anatomical models. In fact, some students stated so in the course evaluation forms that were collected at the end of the semester. One student commented: "the iPads are great. However, there is a learning curve to using them and that cost us instruction time in the lab." Because the post-lab quizzes were given only during the first seven weeks, the long-term effects of these tools in learning outcomes are beyond the capabilities of this study. Additional research would be needed to determine the long-term effects of these strategies.

After the eighth week of lab instruction, both the control and intervention groups had access to the same educational tools. This was decided in order to allow all students to obtain the potential benefits of using the supplementary tools. The questionnaires collected at the end of the semester showed that students enjoyed the audiovisual and interactive tools. Therefore, it appeared that once they overcame the initial learning phase, most students were comfortable with the new methods.

Efficient use of faculty time is a must in healthcare programs. According to the students' perceptions, the enhancing plan did not seem to help them to become more independent from the instructor (3.2±0.95 in the five-point Likert scale; Q7, Figure 2). However, as instructor I observed a decrease in the amount of time I needed to devote with students reviewing essential concepts compared to the previous year's class.

In the students' questionnaire responses, dissecting videos were selected as the most effective instructional tool (40% of the responses; Figure 3) and also as the best liked along with iPad applications (39% of the responses for each method; Figure 3). This could be consistent with a high prevalence of visual learners within the subjects of our study. However, there might be additional reasons that would explain why the clinical scenarios and the preparation of critical-thinking questions did not reach the same levels of popularity as the dissection videos. Most likely, the type of activities that promote problem-based learning and metacognitive skills require the utilization of higher-order cognitive skills. Thus, possibly our students needed to dedicate a substantial effort to solving the clinical scenarios and writing the critical-thinking questions. I believe this may explain why fewer students selected these two learning tools in the questionnaire.

Regarding their benefits toward learning, iPad applications scored surprisingly low (14% of collected responses) followed by critical-thinking questions (19% of collected responses), clinical scenarios (26% of collected responses) and dissection videos (the preferred one; 40% of collected responses). Very interestingly, although students really liked the iPad applications, they ranked critical-thinking questions and clinical scenarios higher when it came to their educational value. Some of the students' comments were striking, such as 1) "maybe the lab can be more structured instead of letting us loose on our own"; 2) "instructors could do a short briefing so that we stay on the right track"; 3) "instructors could use the iPads together with us." These comments and others along the same lines suggested that high levels of learner control might have been, to some extent, detrimental for learning. As demonstrated by Steinberg[16], this situation might be of special concern if students have limited pre-existing knowledge in anatomy and/or limited metacognitive skills.

Conclusion

The results of this study suggested that iPad applications, dissection videos, clinical scenarios and critical-thinking questions are instructional resources that can be successfully incorporated into the gross anatomy laboratory. Although the supplementary approaches used in this study did not seem to improve learning outcomes, students liked them. Thus, the use of these materials might boost their interest for learning anatomy. The fact that our students needed to get accustomed to some of the supplementary tools (e.g., iPad applications) was a limitation of this short-term study and, perhaps, a long-term experience involving a higher number of students would have uncovered different results. Nevertheless, for future studies, it would be wise to realize that this initial learning period might be distractive for students and might even interfere with their learning. To my knowledge, this is the first study of this kind performed in an optometry school. The results obtained could be also relevant to additional health sciences programs not using cadavers in their labs.

Acknowledgements

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Value Added Assessment of Private Practice Externships

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Abstract

Private practice settings provide important educational experiences for optometry students, with opportunities for both clinical and practice management exposure. Challenges exist for both the private practice and the affiliated educational institution. These challenges include assuring an appropriate educational experience for the student, integrating the extern into the practice, and developing the private practice preceptor into a clinical educator.

This project assessed what components are important in establishing "Optometric Centers of Excellence for Private Practice Specialty Education" and compared the specialty (vision therapy/pediatric) private practice experience with an institutionally based specialty externship. The phases of the project included planning and development, implementation and outcomes assessment. Criteria for site selection, site visitation and assistance in developing the private practice preceptor into an educator are essential components in establishing private practice externships. The specialty private practice externships were found to have a value added component that included a broader patient population, greater variety of clinical education opportunities, and increased understanding of practice management skills.

Key Words: *private practice externship, externship, private practice, clinical education, practice management*

Dr. Adamczyk, a 1985 graduate of the Pennsylvania College of Optometry and former resident at the Newington Veterans Administration Hospital, has been a faculty member for more than 25 years at the State University of New York, State College of Optometry, where she is currently a Professor. She is also the Director of Residency Education. Dr. Adamczyk lectures nationally and internationally and has published on a variety of topics, including ocular pharmacology, primary care and ocular disease.

Dr. Mozlin graduated from the New England College of Optometry in 1981. In 1982, she completed the Residency in Vision Training at the State University of New York, State College of Optometry, where she has remained a member of the faculty and is currently an Associate Clinical Professor. In May 2003, she completed a master's degree in Public Health at New York Medical College's School of Public Health. She is a Fellow of the American Academy of Optometry and the College of Optometrists in Vision Development. Dr. Mozlin has lectured extensively and published many articles on vision therapy, learning related vision problems, optometric education and public health.

Background

Private practices or non-institutionally based settings provide important educational experiences for optometry students as sites for their clinical rotations. In addition to the clinical education component, private practices can provide a practice management opportunity for the student, with exposure to the day to day running of a successful office. The private practitioner gains the benefits associated with being affiliated with an educational institution, professional recognition, and the development and ultimate status of being an educator with a student extern in the office. However, concerns from a private practitioner perspective include how the extern will integrate into the practice, how patients will react to a student practitioner, and liability issues. Important issues for the academic affiliate include assuring the student extern will receive an appropriate educational experience and assisting the private practitioner in becoming an educator.

In 2008, upon receiving an educational grant from Vision Service Plan (VSP), the State University of New York (SUNY), State College of Optometry began a methodical and detailed process to establish externships for its fourth-year students in private practices with a specialty emphasis. The purpose of the grant was to provide students with clinical opportunities, coupled with a practice management component, in a private practice with a vision therapy (VT) emphasis. In addition, the project focused on assisting the doctors in their development as clinical educators. Until that time, SUNY had not utilized private practice settings as part of its externship program. These new externship programs were known as "Optometric Centers of Excellence for Private Practice Specialty Education."

The project had several phases, which progressed from planning and development to implementation and ended with an outcomes assessment of the project. A comparative analysis of clinical experience was made between the fourth-year students who participated in the private practice experience and the fourth-year students who participated in an institutionally based VT/

pediatric externship located at the University Eye Center of the SUNY State College of Optometry. The private practice externs were also surveyed as to their perceived change in practice management knowledge before and after the externship. A final assessment at the conclusion of this pilot program helped to pinpoint important lessons learned.

Methods

This pilot project was divided into five phases: planning and development, site selection, training, implementation and final assessment.

Phase 1: planning and development

A consultant with expertise in VT/pediatrics and private practice management was hired. Although she assisted in the project's development and site selection, her primary role was to provide direction to the private practitioners in integrating the student extern into their practice, as well as their development as clinical educators. She had significant experience in providing clinical education within her practice to students from several other schools and colleges of optometry. With the guidance of the consultant, selection criteria were developed. The criteria focused on finding the best practices that could meet the goals of the program and assure that students placed in different practices would receive a similar educational experience. An application process was developed with selection criteria that included:

- full-time practice
- minimum of 50% of patient encounters are VT or pediatric related, and a minimum of 10% of patient encounters are primary care
- minimum of 30 VT sessions/pediatric exams per week
- no prior externs in practice
- at least one therapist
- dedicated therapy room with appropriate equipment
- minimum of two exam rooms
- must deal with insurance plans
- have a plan to build the practice, and evidence of practice growth
- more than one office staff personnel
- evidence of self-education (attends meetings, reads journals, etc.)
- willingness to open financial/accounting records to student
- evidence of working with other disciplines (education, occupational therapy, speech therapy, nutrition, etc.)
- willingness to invest a minimum of one hour per week in student's education (outside of patient care)
- commitment from staff and other doctors to participate in student's education.

The planning phase also included an extensive review of legal and malpractice issues. SUNY's legal counsel reviewed the relevant optometry laws, first in New York then in the other states in which private practice externship sites were being considered. Review of state law as it relates to patient care provided by students in training was essential prior to the selection of the private practice externship site. This identified requirements and limitations in students' provision of patient care as defined by state law.

Phase II: site selection

A recruitment announcement seeking practices for this study was sent to members of the College of Optometrists in Vision Development (COVD). In addition, doctors with practices known to potentially fulfill the criteria throughout the country were contacted and asked if they were interested in developing this affiliation. Doctors expressing interest in participating in the study were asked to complete an application. A total of eight completed applications were received. Of these eight, five practices were visited by one of the grant's principal investigators and the private practice consultant.

Three practices were chosen. In order to guarantee access to all students without the investment of significant financial resources, one of the selected practices was in the New York City area. The other two practices, both in California, were chosen without regard to geography. All three practices were deemed the most appropriate for the study based on the selection criteria.

Phase III: private practice affiliation and student selection

Each practice received supplemental information outlining a practice management curriculum and expectations for performance of fourth-year student clinicians. This information included a private practice manual specific for SUNY. The manual contained the goals, objectives and curriculum for the externship, including the practice management aspect, copies of evaluation forms, grading policies and procedures, a supervisor primer and descriptions of didactic courses particularly pertinent to VT and pediatrics. In addition, the COVD Externship Manual was given to the externship supervisor. Affiliation agreements were written with legal consultation, and practitioner credentials were verified.

With these externships starting in June 2009, student selection occurred in the fall of 2008. Three private practice externships were assigned one fourth-year student per quarter, for a total of 12 students for the year. They were selected from a pool of 15 students who applied specifically for these private practice externships. Application for these sites included a written statement of interest in both private practice and VT. In contrast, two to three students per quarter were assigned and participated in the in-house, institutionally based VT/pediatric externship, for a total of 10 students for the year. These students were selected as part of the normal selection process for externships, which included their ranking of requested sites and typically included a written narrative expressing the student's interest in those externship sites.

Phase IV: implementation

Development of the private practice externship supervisor into an educator

In October 2008, the three private practice doctors participated in a training program to assist them in becoming a preceptor and clinical educator. This was done during COVD's annual meeting. Administrative policies and procedures were reviewed. The doctors were given an overview of the coursework and clinical experiences the students received during their second, third and fourth years to help them define expectations for students' clinical performance and grading. A review of

the grading guidelines in the externship manual provided a segue into a discussion of effective clinical teaching. The doctors were encouraged to invest time in orienting the students to office policies and procedures as well as discussing with each student their individual interests and goals for the externship. After observing the student's clinical skills and other patient care competencies, an appropriate schedule of patient care activities could then be developed to meet both the private practice and student extern needs. The practitioner was required to develop a manual specific for the extern that provided an overview of the policies and workings of the office. This was meant to assist in the integration of the student into the practice. The essential nature of feedback and flexibility in the clinical education process was emphasized. Additionally, a practice management curriculum was given to the practitioner, with topics to be discussed with the extern. Topics included economics of a VT practice, marketing and promotion, and office management.

Just prior to the arrival of the students, a follow-up conference call to answer questions and re-emphasize key aspects discussed at the training program occurred. The consultant participated in the training program and conference call and was also available to the practitioners to answer questions whenever needed. The consultant was instrumental in helping the doctors prepare for the integration of the student extern into the practice.

Monitoring student experiences

All fourth-year student externs were required to use Meditrek (a commercial Web-based data collection service) to keep detailed logs of their patient encounters and to complete an evaluation of the externship. This enabled a comparison of the patient care and educational experiences of the private practice externs to that of externs at other sites. The private practice externs also evaluated the practice management component of their externship experience.

The private practice externs completed an additional survey, one before they entered the private practice externship site and one after, to assess their perceived knowledge in areas of practice management. A comparison and assessment was made of the difference in the extern's perceived practice management knowledge before and after exposure to a private practice setting.

Phase V: final assessment

A focus group, consisting of the three private practice doctors, the consulting doctor and the two authors, was convened at the completion of the year to discuss the project and the findings and to make recommendations for improving the externship experience. Areas reviewed included the student private practice experience as compared to that of the institutional experience, the integration of the student into the private practice, and the development of the practitioner into an educator.

Because of the lead time required for both practice and student selections, followed by the actual externship rotation time, the entire project required 2.5 years to complete.

Results

Site selection and state laws

Two of the private practices were located in California and one was located in New York. In conjunction with legal counsel, both the New York and California optometry laws were reviewed. Both states have stipulations in their laws that relate to optometry student practitioners. In New York, Section 7105 of the Education Law stipulates that a student may engage in clinical practice under the supervision of a licensed optometrist or physician in a school of optometry registered by the department of education. Therefore only students enrolled in a New York State school of optometry may practice under the supervision of an optometrist or physician. In California, the state's Business and Professional Code 3042.5 (student and instructor exemptions) delineates that the student practitioner must be enrolled in an accredited school or college of optometry as part of their study of optometry.

Private practice externship vs. institutional experience

All selected students for both the private practice (n=12) and the institutionally based VT/pediatrics program (n=10) completed their externship rotations. All externs completed their required patient logs and externship evaluations in Meditrek. The private practice externs also completed the pre- and post-externship survey that related to their perceived level of practice management knowledge.

A comparison of the average number of patients seen per quarter by demographics, billing code, diagnosis, exam type and assessment can be found in **Table 1**. The private practice externs saw an average of 378 patients in comparison to 287 patients for VT/pediatrics externs. Externs in both programs saw the greatest number of patients in the age range of 6-17 years, with the private practice externs seeing a wider range of ages beyond this group **(Figure 1)**.

The private practice externs saw more established patients than the institutionally based externs (202 vs. 54). The VT/pediatrics externs billed on average 147 VT sessions and the private practice externs billed an average of 101. The VT/pediatrics externs used the sensorimotor billing code approximately twice as often as the private practice externs (27 vs. 15) **(Figure 2)**. Looking at the various VT exam types seen, the VT/pediatrics externs had an average of 177 vs. 127 seen by the private practice externs. However, the private practice externs saw a greater variety of exam types, including contact lens and primary care.

The top three diagnoses were the same for both externships: refractive/accommodative disorders, amblyopia and binocular dysfunctions, and strabismus. The private practice externs had a significantly greater average number of refractive/accommodative diagnostic encounters (230 vs. 106) and the VT/pediatrics externs had a greater average number of strabismic diagnostic encounters (46 vs. 29) **(Figure 3)**.

When compared to the institutional VT/pediatrics externs, the private practice externs indicated greater improvement in overall clinical skills, doctor/patient communication and prescribing skills **(Table 2)**. They also rated the overall experience slightly higher than the institutionally based externs (4.7 vs. 4.4 out of 5). The institutionally

based externs felt they had greater improvement in new clinical procedures, examination skills and use of ocular pharmaceuticals.

In comparing the private practice extern's self-assessment of their practice management knowledge, pre- and post private-practice experience, the externs indicated improvement in all areas surveyed **(Table 3)**. The areas of greatest improvement in practice management knowledge included utilizing space and equipment, educating patients/parents on the goals of a personalized vision therapy program, and marketing and promotion to build a practice.

Based on discussions the doctors had with their externs, each private practice externship supervisor was asked to predict how many of their students would become private practitioners. The predictions ranged from 50% to 100%.

Final focus group results

The focus group, which consisted of the private practice supervisors, consultant and the two authors, identified the following key points:

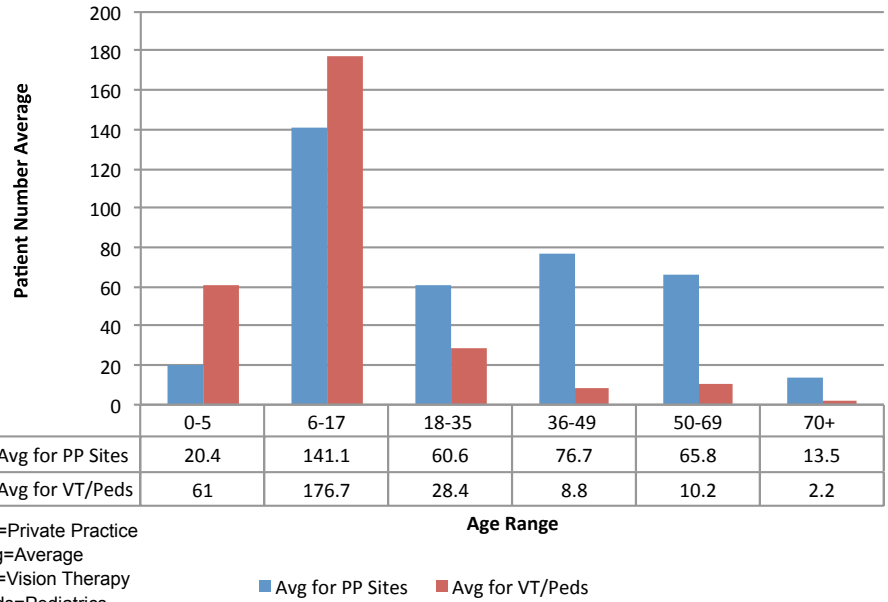
- The initial concern that patients would not welcome the idea of being examined by a student extern did not occur, with only a rare exception.
- A structured practice management curriculum was difficult to implement because of the varying interests of each extern, but the students were able to learn a great deal informally.
- Office staff were open to the externs and to participating in their experience.
- Creating a manual for the extern in regard to office policies, etc., as they apply to the extern was helpful in the integration of the extern into the practice.
- The private practitioners appreciated the time and resources spent by the affiliate to help them navigate administrative procedures as well as become better clinical educators.
- Experience and confidence in teaching developed over time and any additional instructions on teaching would be helpful.

Table 1
Patient Log Averages for Private Practice Sites and VT/Pediatrics Site

	Average for PRIVATE PRACTICE Sites	Average for VT/Pediatrics
AGE		
0-5	20.4	61
6-17	141.1	176.7
18-35	60.6	28.4
36-49	76.7	8.8
50-69	65.8	10.2
70+	13.5	2.2
GENDER		
Male	178.1	159.2
Female	200	128.1
TOTAL # OF PATIENTS	378.1	287.3
BILLING CODES		
92004 Comprehensive/New	47.5	55.8
92014 Comprehensive/Established	149	24.9
92012 Intermediate/Established	52.5	29.5
92060 Sensorimotor	15	27.4
92065 VT Session	101.4	146.6
DIAGNOSIS		
362 Other Retina	6	1.9
366 Cataract	14.8	0.7
367 Refractive/Accommodative	229.8	106.4
368 Amblyopia/Binocular/Visual Field	99.1	108.2
370 Keratitis	5.5	0.2
371 Cornea	12.5	1.2
372 Conjunctiva	6.5	1
373 Inflammation Eyelids	6	1.6
378 Strabismus	28.8	46
379 Other	5.5	29.8
EXAM TYPE		
Primary Care	185.2	73.7
CL Fit	36.5	0.4
CL Follow up	28.9	0.2
Postoperative	5.1	0
VT Evaluation/Workup	20.2	17.9
VT Skills	9.3	18.1
VT Session	95.1	135.7
Other	2.5	5.9
ASSESS INCLUDED		
Soft Toric CL	16.4	0.5
Multifocal CL	10.5	0
RGP Fit	14.7	0
SCL Fit	29.8	0.2
Visual Fields	61.7	1.8
Photography	89.2	0.4
Imaging	5.3	0.7

Note: There were 10 VT/Pediatrics students and 12 Private Practice students
CL=Contact Lenses
LV=Low Vision
RGP=Rigid Gas Permeable
SCL=Soft Contact Lens
Above listing includes averages >5 in one or both sites

Figure 1
Age Range Seen by Private Practice and VT/Pediatric Externs

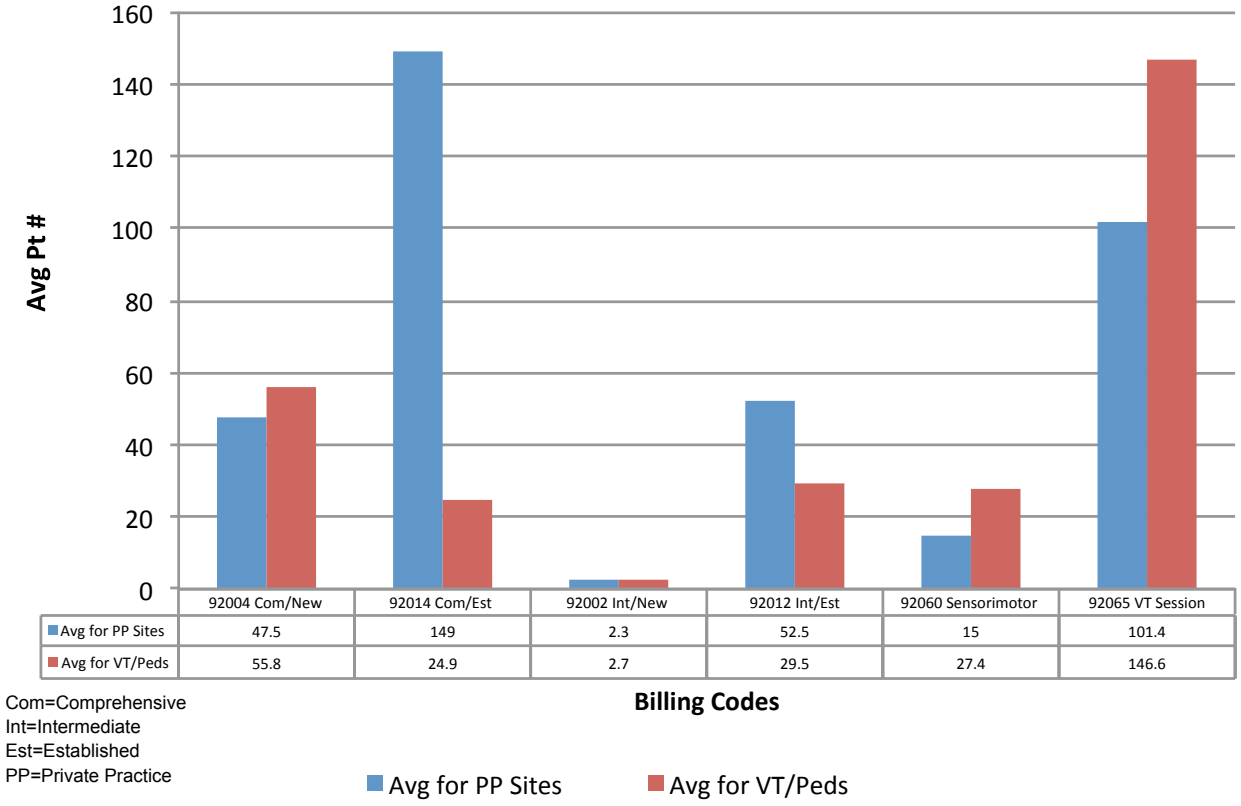


	0-5	6-17	18-35	36-49	50-69	70+
Avg for PP Sites	20.4	141.1	60.6	76.7	65.8	13.5
Avg for VT/Peds	61	176.7	28.4	8.8	10.2	2.2

PP=Private Practice
Avg=Average
VT=Vision Therapy
Peds=Pediatrics

Figure 2

Billing Codes Used by Private Practice and VT/Pediatric Externs



	92004 Com/New	92014 Com/Est	92002 Int/New	92012 Int/Est	92060 Sensorimotor	92065 VT Session
Avg for PP Sites	47.5	149	2.3	52.5	15	101.4
Avg for VT/Peds	55.8	24.9	2.7	29.5	27.4	146.6

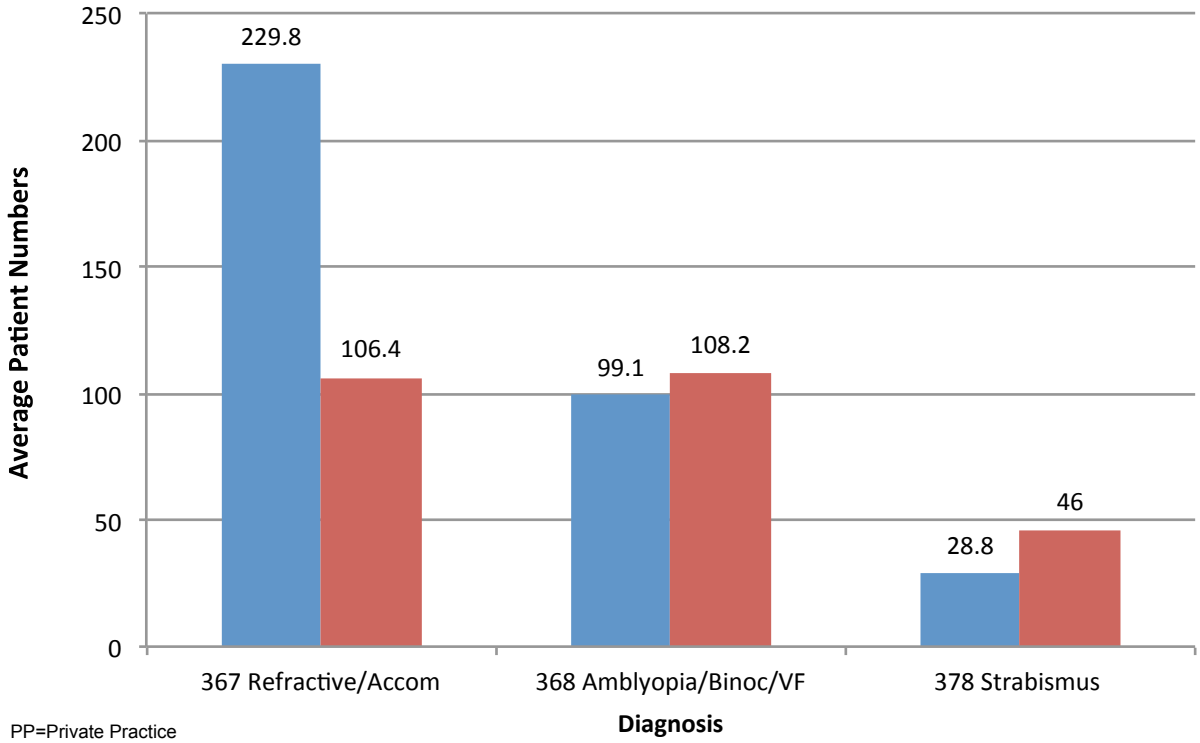
Billing Codes

Com=Comprehensive
Int=Intermediate
Est=Established
PP=Private Practice

Avg for PP Sites Avg for VT/Peds

Figure 3

Top 3 Diagnoses at Private Practice and VT/Pediatric Sites



PP=Private Practice
Avg=Average
Accom=Accommodative
Binoc=Binocular
VF=Visual field

Avg for PP Sites Avg for VT/Peds

Discussion

Private practice externships provide an important opportunity in all healthcare professions. These externships sites provide not only a clinical education, but also exposure to the daily workings of an office, with opportunities to gain practice management knowledge. The private practice may alter and direct the professional path of the student extern. In medicine, office-based pediatric clerkships have been found to influence students toward pediatrics as a career choice, as well as provide students with an insight into the workings of an office.[1] Similar positive findings were found with private surgical practice experience for medical students. This exposure, which was only four days, changed student's perception of the surgical lifestyle and swayed some to consider surgery as a career option.[2]

Once the decision is made to embark on the provision of private practice externships, it is necessary to define the educational experience that the practices would be expected to provide to the students. Well-defined program goals and objectives are important in establishing private practice programs, as well as in setting practitioner selection criteria.[3] Therefore, developing criteria for practice selection is a critical first step, followed by the development of an application that reflects the criteria for the private practice externship. It is then the responsibility of the schools and colleges of optometry to find the practices best suited to deliver the educational experience it desires.

In addition to establishing the criteria for site selection, once a site is being considered for selection, it is critically important to review the state laws that govern the practice of optometry to determine if specific considerations or regulations are present for student practitioners. Therefore, an analysis of the state laws and statutes must be made to determine if there are boundaries and/or limitations in the delivery of care by student clinicians in a private practice setting. Every state has different laws and may present different legal and liability issues surrounding the provision of optometric care by students. This was found with the two states involved in this pilot study. Specific requirements and considerations were found for each state.[4,5] Determination of these types of requirements is crucial for the protection of the practitioner, the student, the patients and the affiliated school or college of optometry.

In addition to a review of the optometry state laws, malpractice and billing considerations should be addressed. Although the student is covered under the academic institution's malpractice insurance, as typically is delineated in the affiliate and practice's memorandum of understanding or affiliation agreement, it is recommended that the practitioners review their own malpractice policies and notify their carrier. The practitioner should also be advised to follow all regulations for appropriate billing.

Visiting the private practices under consideration as externship sites is critical. Meeting office staff, assessing office location and equipment, and observ-

Table 2
Students' Evaluations of Private Practice Experience Compared to Students' Evaluations of VT/Pediatrics Experience

	PRIVATE PRACTICE Sites Average	VT/Pediatrics Average
This external clinical education rotation benefitted my education in:		
Improving my examination skills	4.4	4.6
Improving my diagnostic skills	3.9	4.3
Improving my patient/doctor communication skills	4.6	4.2
Improving my prescribing skills	4.4	4
Understanding ocular pharmaceuticals and their use	2.9	3.3
Understanding systemic health problems	3.2	3.3
Learning new clinical procedures	4.1	4.8
Learning to use new clinical instrumentation	4.2	4
Patient treatment and management	4.4	4.3
Improved overall clinical skills	4.6	4.2
Patient encounters were sufficient	4.6	4.3
The overall experience was excellent	4.7	4.4
The Private Practice Experience improved my understanding of:		
Patient management in a VT/Pediatrics practice	4.8	
Economics of a private practice	3.9	
Marketing and promotions of a private practice	4.1	
Office management	3.9	

SCALE:
1=Strongly disagree
3=Neutral
5=Strongly agree
Note: 10 students completed evaluations for the VT/Pediatrics rotation, 12 students completed evaluations for the Private Practice rotation

Table 3
Pre Rotation Assessment Compared to Post Rotation Assessment

	PRE Average	POST Average
I have the understanding and skills to perform these functions in a private practice:		
Scheduling patients for different types of appointments	3.4	3.8
Educating patients/parents on the goals of a personalized vision therapy program	3	3.9
Written communication/report and letter writing	2.8	3.3
Structuring fees and a billing system in a private practice	2.2	3
Coding and documentation	2.7	3.2
Managing insurance plans/managed care	2.3	3
How to obtain financing to open a practice	2.2	2.4
Marketing and promotion to build a practice	2.3	3.3
Hiring/managing staff	2.3	3
Choosing and maximizing the use of practice management software/technology	2.1	2.9
Utilizing space and equipment effectively	2.6	4

SCALE:
1 = No skills or understanding
3 = "Entry level" skill and understanding to function in a private practice but still learning
5 = Moving beyond the basics toward mastery

ing patient care in action provide the opportunity to evaluate the quality of the educational and practice management experience the students would be receiving. This study demonstrated the multifaceted nature of choosing private practices that are most likely to be successful externship sites. The application, a thorough review of state laws, the credentials of the preceptor and the site visit all contributed to the selection process.

During this pilot project, a number of training mechanisms were put into place. The private practice supervisor was provided both the COVD externship manual and the college's externship manual, specific for private practices. The manuals provided general information about having a student extern in the office, with the college's manual providing specifics as to the administrative tasks associated with the externship, such as grading and managing planned absences. The college's manual served as a supervisor primer and included the mission, goals and objectives of the program, the curriculum for the private practice externship and what to expect from students, along with descriptions of the didactic courses the student had completed, particularly in the area of binocular vision.

It was equally important to provide the practitioners with guidance on integrating the extern into their practices. Here, the consultant was able to provide practical and firsthand knowledge concerning bringing an extern into the practice. Formal support from the consultant occurred during meetings and conference calls and was effective at increasing the practitioners' level of comfort as they incorporated the supervision and education of the externs into their practices. The three practitioners also discussed their ideas and concerns with each other and learned a great deal from sharing their experiences. This included an enhanced understanding of the variability in student performance and the need for recalibration of expectations every three months, when a new student arrived who had more clinical experience than the previous student.

In addition, each practice was required to develop its own extern manual specific to its office. This also provided an opportunity for the practitioners to share ideas with each other. These manuals included various office policies (dress code, office hours, holidays, etc.). Some manuals included the precepting doctor's goals for the extern, a welcome to the extern, an overview of the doctors in the practice, and philosophy of patient care. In addition, one practice requested an essay prior to the externs entering the practice that provided an overview of the externs, what their goals were, hobbies, educational history, and why they chose optometry as a profession. Creation of a manual provided not only guidelines to the student, but also to the staff.

Optometrists serving as clinical educators are often chosen or thrust into this role because of their clinical skills, expertise or practice setting. They typically have little or no training in clinical education. The challenge of providing clinical education in a busy private practice setting is perhaps amplified when the doctor's livelihood is somewhat dependent upon the patient's perceptions of the student's roles and responsibilities. The schools and colleges of optometry have long understood their obligation to support clinical educators in all clinical settings.[6] At a minimum, clinical supervisors should receive information and training to understand their expected roles and responsibilities, teaching methods, expected student learning outcomes and curriculum.[7,8] The private practitioners in this study were encouraged to follow a model of clinical education based on Davis' teaching strategies that was described by Tolls, Carlson and Wilson:[9]

- write objectives and describe tasks
- assess learner's entry behaviors
- identify needed skills vs. possessed skills
- design instructional modules
- implement instruction with feedback and reinforcement
- conduct evaluation
- revise instructional modules.

Despite all the resources to which they had access and their increasing confidence over time in their effectiveness as clinical educators, during the final assessment, all three private practitioners agreed that they wanted more instruction in clinical education. They were very open to the use of technology to accomplish this, such as webinars, videoconferencing, etc. Other professions have explored pushing beyond the limits of face-to-face "preceptor training." In nursing, it was found that the average preceptor orientation program was 2.5 hours, which was considered an inadequate amount of time.[8] Preceptor training can be done through a variety of mechanisms, including handbooks, orientations, a formal training program and online training.[3,10,11] Online modules can provide a self-paced course to educate preceptors.[10-12] These courses may be cost-effective and can include a variety of topics. Irrespective of the mode of training, areas that should be covered include clinical teaching strategies, supervising the student, evaluation, critical thinking and integrating the student into the practice.[10-12] In addition to this training, it is important that frequent and effective communication occurs between the affiliate and the preceptor. This study confirmed the importance and responsibility of the school or college of optometry to provide the private practitioner with the training needed to become a clinical educator who will meet the mission and goals of the educational program.

In looking specifically at the externship experience, this study was able to compare the externship experience of students in a private practice with a specialty in VT/pediatrics vs. an institutionally based VT/pediatrics program. The private practice experience provided not only a greater number of patient exposures, but also a broader range of ages, greater variety of exam types, assessments and diagnoses in comparison to the institutionally based externship. Although the top diagnoses between the two groups were similar, the private practice externs saw more accommodative/refractive cases and the institutionally based externs saw more strabismic patients. Of interest, the private practice externs performed more primary care examinations than anticipated and saw a significant numbers of patients requiring contact lens care.

The private practice experience was found to increase the students' understanding of practice management. This included a variety of areas associated

with running a practice: patient scheduling, fees and billing, marketing, space and equipment needs and utilization, and marketing. An understanding of various communication skills was also increased. When compared with the institutional VT/pediatrics externs, the private practice externs noted greater improvement in the area of patient-doctor communication skills. The private practitioners all agreed that it was difficult to teach practice management in a formal/didactic format. The students learned from observing the workings of the practice, which was then supplemented by the doctors providing practice management information that depended on the student's individual motivation and interest in this area. Because these students initially expressed an interest in both a private practice setting and vision therapy, the private practice externship may play an important role in helping them decide if they should continue to pursue private practice as their professional career path. A five-year follow-up would be of interest with these students to see if the private practice experience had an impact on their career choice.

Other salient points from the private practice experience included the following. The practitioners and the authors agreed that site selection is crucial for a successful externship rotation, with site visitation important. An initial concern of all the practitioners was the receptiveness patients would have to involvement of a student extern involved in their care. It was a rare instance that a patient was not receptive to being seen by the student. This receptiveness was attributed to educating the patients on the student's role, presenting the extern in a confident manner and explaining to patients that the doctor would still be actively involved in their care.

In summary, establishing successful private practice externships includes the following: delineation of criteria for site selection, investigation of state laws as they relate to student practitioners, development of a site selection process that includes a site visit that assures a good match between the program and affiliate, and provision of guidance in educating the student to the private practitioner.

Conclusions

Specialty private practice clinical rotations offer unique educational experiences and opportunities to the student in comparison to an institutional setting. The value added component of a private practice experience includes a broader patient population, greater variety of clinical educational opportunities, and an increased understanding of practice management skills. In addition, a private practice externship may influence the practice setting the student ultimately pursues.

The three practices selected for this pilot study continue to serve as externship sites for SUNY's fourth-year students. The best practices and lessons learned during this project can be used by other schools and colleges of optometry and applied to other specialties. These include establishment of site criteria, investigation of state regulations for student practitioners, site selection including site visitation, and ongoing discussion and guidance to the private practitioners to strengthen their teaching skills. These are likely to become more cogent as the number of optometry students requiring or seeking clinical education in a private practice setting increases.

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Carbon Monoxide and the Eye: A Teaching Case Report

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Abstract

Both acute and chronic exposure to carbon monoxide (CO) gas can have serious and permanent effects on a person's health and vision, especially if left untreated. The brain and eyes are at risk upon exposure to this clear, odorless gas due to the large oxygen demands of these structures. This teaching case report highlights the need for eyecare professionals to recognize the possible ocular, systemic and neurological effects of CO poisoning and the impending long-term risk factors. This report also reviews the body's response to acute hypoxic events, including ocular and systemic symptomatology, the testing and procedures used for the differential diagnosis of CO poisoning, the events and risk factors leading to CO poisoning, the pathophysiology of CO on the body, and the treatment options for CO poisoning from the perspective of an eyecare provider.

Key Words: *carbon monoxide, carbon monoxide poisoning, CO poisoning, CO exposure, acute carbon monoxide poisoning, carboxyhemoglobin, ocular CO poisoning, diplopia, double vision*

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Background

It is well-documented that both acute and chronic exposure to carbon monoxide (CO) gas can have serious and permanent effects on a person's health and vision, especially if left untreated. Carbon monoxide is poisonous to the human body specifically because it binds to hemoglobin 225 to 240 times more tightly than oxygen. This results in a reduced oxygen-carrying capacity and the inability of oxygen to be distributed throughout tissues.[1] The extent of this damage depends on the concentration of the inhaled poisonous gas and the length of exposure. The parts of the body most affected by CO poisoning are those most susceptible to hypoxia.[2] Naturally, the brain and eyes are at risk upon exposure to this clear, odorless gas due to the large oxygen demands of these structures. This teaching case report provides a comprehensive evaluation of a unique case of systemic etiology that presented in an optometry clinic with both systemic and ocular symptoms. Specifically, it addresses the clinical techniques and diagnostic tests needed to come to the right diagnosis, and it evaluates the ancillary tests required to rule out other possible causes.

This teaching case report is appropriate for all levels of learners. For first- and second-year students, the recommended emphasis is an application of basic science to explain clinical presentation, elements of a thorough case history, and test selection. For third-year students, fourth-year students and residents, the same concepts can be emphasized, and the additional concepts of clinical application, assessment and management, and the optometrist's role on the healthcare team can be discussed.

Student Discussion Guide

Case description

Patient AK, a 24-year-old Caucasian female, presented at the Atwater Eye Care Clinic for a comprehensive ocular examination. She complained of a sudden onset of double vision, blurred vision, nausea, headaches and malaise on multiple occasions in the few days prior to the exam. She stated that she was in excellent health. She first noticed her blurry vision lasting 10-20

minutes when running on the Friday prior to the exam and noted multiple recurrences throughout the next few days. Upon further questioning, the patient noted that symptoms were worse when at home. When asked about the conditions at home, she explained that her furnace had made a loud sound and malfunctioned in the middle of the night prior to initiation of symptoms. She reported that due to the temperature in the house, she had limited her time at home when she could. In fact, she did not spend the night before the examination at home and had only been in her home for an hour several hours before the exam.

At the time of the examination, she was not experiencing any symptoms that she had intermittently experienced. Her medical and ocular history were unremarkable, and she denied having any surgeries, environmental allergies or drug allergies. Her current medications included a daily multi-vitamin, fish oil, and Apri (desogestrel and ethinyl estradiol tablets). She stated that she had smoked socially in the past but was not a current smoker. She was oriented to time, place and person, and her mood and affect were normal.

The patient's pupils were equal, round and reactive to light and accommodation without afferent pupillary defects OU. Extraocular muscle versions were full and smooth OU without pain or diplopia, and Humphrey visual field 30-2 Sita-Standard testing was unremarkable OD and OS. Cover test revealed orthophoria at distance and a small (2 prism diopter) esophoria at near with no vertical deviation. Worth 4 dot testing was within normal limits at all distances under normal illumination. Fixation disparity testing with Saladin card revealed orthophoria at distance and near. Her habitual spectacle prescription was -0.75D OU, but she did not wear glasses regularly. Refraction yielded a best-corrected visual acuity of 20/20 OD and OS with a prescription of -0.75D OD and -1.25D OS. Negative relative accommodation (NRA), positive relative accommodation (PRA) and fused cross cylinder (FCC) were measured at +2.00, -1.50 and +1.25 respectively. Blood pressure was taken from her right arm while she was in a seated position and measured 110/78.

Slit lamp examination of the anterior segment was unremarkable. Her intraocular pressures were measured at 13 mmHg OU with Goldmann Applanation tonometry. Dilated fundus evaluation of the posterior segment using a +90D lens revealed healthy optic nerves with a cup to disc ratio of approximately 0.35/0.35 OU, healthy retinal vasculature and a healthy macula OU. Binocular indirect ophthalmoscopy using a +20D fundus lens revealed a flat and intact retina 360° OU with unremarkable findings.

Lab testing

Subsequent to the ocular examination, the patient was sent to the Indiana University Student Health Center for blood testing. Complete Blood Count (CBC), arterial blood gases and carbon monoxide blood testing were completed at 4:46 p.m. the same day. Arterial pH was found to be 7.52 (normal range = 7.35-7.45), HGB arterial blood gases were 14.8 G/dL (normal range = 12.0-17.0), arterial carbon monoxide was 0.8% (normal range = 0.0-3.0) and CBC was within normal ranges. Additional results were also unremarkable.

Follow-up call #1: two days after initial presentation

The patient reported that she had not experienced similar symptoms since her examination. Since then her heater/furnace had been turned off pending a replacement unit, and she had purchased and installed a CO detector. No extreme levels of CO had been detected since installation.

Follow-up call #2: three weeks after initial presentation

The patient reported no visual disturbances of any kind since the examination. She also noted that the heating unit issues had been fixed and that her CO detector had not indicated any abnormal levels. The patient was asked to call in if any symptoms or issues developed.

Educator's Guide

Literature review

Although carbon monoxide poisoning does not commonly present to an ophthalmic clinic, it is a significant issue that could have severe consequences if not recognized early by the clinician. Nearly 70,000 cases of CO poisoning were reported in the United States between 2000 and 2009, with headaches and nausea presenting as the most common symptoms.[3] Other studies have shown that blurred vision, photophobia and diplopia can also be associated with CO exposure.[4-6] Males and females are equally susceptible, and CO exposures occur most commonly during the winter months with 77.6% of cases at residences.[3] Most frequently, exposure to poisonous amounts of carbon monoxide occurs due to a faulty heating unit within a building. Other sources of high levels of CO exposure are automobile accidents and suicide attempts.

Many studies have attempted to identify the threshold value of CO exposure needed to cause harmful effects on the human visual system. It is known that large amounts of CO exposure will cause visual dysfunction and is made evident by high carboxyhemoglobin (COHb) levels.[5] However, the CO exposure threshold that causes visual symptoms is highly controversial. Hudnell and Benignus concluded that COHb levels at 17% or lower are not detrimental to the visual luminance and contrast detection in young, healthy males.[5] They came to this conclusion by observing the susceptibility of the human contrast sensitivity threshold and critical frequency flicker, which is the highest light frequency at which flicker is observed. This study showed that neither the contrast sensitivity threshold nor the critical frequency flicker were adversely affected at this COHb level.[4] Other reports show that "slight" adverse effects were observed at a COHb level of 18% after exercise.[5]

Systemic symptoms of exposure are considered non-specific and include headaches, irritability, nausea, dizziness, myalgias, lethargy and other symptoms associated with hypoxia.[2] The literature describes signs associated with CO poisoning to be visual field loss with normal pupillary responses and papilledema at the nasal margin, but these signs are considered rare.[7] Symptoms can present abruptly upon exposure or have a delayed onset. A recent report indicated that 10-30% of patients without any signs or symptoms

upon exposure actually experienced a delayed onset of neurological or psychiatric symptoms.[4] If present, these delayed symptoms have been noted immediately or within days, weeks or even three years after exposure. They may manifest as amnesia, confusion, cognitive dysfunction characterized by attention and working memory deficits, emotional and personality disorders (depression or apathy), incontinence, or motor deficits similar to Parkinsonian symptoms.[4] Research indicates the presence of these late-onset symptoms can be attributed to focal edema or demyelination within the cerebral white matter.[4,8,9] However, it is important to note that many presentations of these late-onset neurological and psychiatric symptoms are based on the location of the defect, and therefore can be very subtle or even subclinical.[4] This report also highlights the potential for saccadic dysfunction as a long-term adverse effect of CO poisoning, but saccadic function can also be disrupted in other neurological disorders and perhaps can only be confirmed as a non-specific sign of neurologic dysfunction.[4] It would be pertinent for an eyecare professional to educate the patient about these possibilities and potentially recommend a referral to a neuro-ophthalmologist for a comprehensive ocular motor assessment (evaluation of saccadic function) or a comprehensive neurologic examination evaluating higher-order cognitive processing, including working memory, response inhibition and attention.[4] With early recognition, the patient can benefit from the application of rehabilitative strategies to address these subtle defects that could be overlooked.[4]

Carbon monoxide is toxic to the human body because it binds to hemoglobin approximately 225 to 240 times more tightly than oxygen to form COHb.[2] Intake of carbon monoxide into the bloodstream causes a leftward shift in the oxygen-hemoglobin dissociation curve resulting in decreased oxygen-carrying capacity. When COHb is formed, oxygen transportation to different organs and tissues in the body is impaired.[2,10] Once a person is removed from the source, carbon monoxide is eliminated from the body during exhalation and has a variable half-life from two to five hours.[2,11,12] Hypoxia and associated symptoms have been reported to occur at carbon monoxide levels greater than 100 ppm or at a COHb concentration greater than 30% in the bloodstream.[10] Surprisingly, inter-individual differences in lung capacity, history of loss of consciousness, gender, age or duration of exposure have not been shown to affect the rate of CO elimination.[13] One study shows that the only factor capable of influencing the rate of CO elimination from the body is the amount of 100% oxygen administered in a treatment setting, which allows a reduced COHb half-life with an increase in administered oxygen therapy.[13]

Parts of the body most susceptible to CO poisoning are those requiring large amounts of oxygen to function, such as the brain and heart.[1] Reports show that CO exposure can cause myocardial dysfunction in the presence of healthy cardiac tissue.[14] The globus pallidus is the part of the brain most commonly affected, but reports also show that other basal ganglia nuclei, the thalamus, brainstem, cerebellum and cerebral cortex can also be involved.[4] The eyes are also highly susceptible to hypoxia, and ischemic changes occur in the retina and optic nerves of patients exposed to CO for more than 12 hours.[15,16] Specifically, the reported signs of ischemic retinopathy and neuropathy are as follows: superficial, flame-shaped retinal hemorrhages, venous tortuosity and engorgement, cotton wool spots, bilateral swollen discs, optic atrophy and retinal edema.[15,10] Gass describes retinopathy due to CO exposure as multiple intraretinal and subretinal hemorrhages resembling those seen in Terson's syndrome.[17] Specifically, Terson's syndrome is characterized by retinal and vitreal hemorrhages associated with subarachnoid or subdural hemorrhages.[17] These hemorrhages associated with both systemic etiologies are caused by a sudden increase in venous pressure that causes peripapillary capillaries to rupture.[17] Other fundus changes seen in CO poisoning are papilledema, venous engorgement and vessel tortuosity.[17] It is uncertain whether ischemic injury to the vascular endothelium is the direct cause of this retinopathy, or if the physical compression of venous vessels by the optic nerve edema plays a more significant role.[17] In general, tissue damage associated with ischemia is characteristically manifested as increased capillary permeability and higher susceptibility to chronic damage.[10]

Due to the susceptibility of the central nervous system to hypoxia, debilitating effects on vision generally have a retrochiasmal origin due to responses stimulated by the neurological system rather than ischemic events within the ocular structures themselves.[4,11] Vision loss and other adverse visual effects due to CO poisoning are considered rare, but neuropsychiatric effects such as alteration of mental state, amnesia, apraxia, Parkinsonism and other conditions listed above are more common manifestations. These effects are considered to have transient or permanent cortical involvement depending on the extent of the exposure.[7] Within the brain tissue, the CO replacement of oxygen on hemoglobin will have an immediate effect and a delayed response. The immediate cellular injury due to hypoxia causes perivascular oxidative stress, which initiates the activation of reactive oxygen species such as NMDA (N-methyl-D-aspartate) and nNOS (neuronal nitric oxide synthase).[18] This oxidative stress cascade and lack of anti-oxidant protection has been shown to promote the neuropathology associated with CO poisoning.[18] This toxic damage and associated hypoxia disrupts the neurovascular autoregulation mechanism and causes endothelial damage to central nervous system (CNS) capillaries.[7] This neuropathology and subsequent hypotension is exaggerated in "watershed" areas of the CNS due to limited anastomoses and their characteristic susceptibility to hypoxia.[7] Delayed damage is caused by extensive lipid peroxidation in the neurons, which depletes overall ATP and leads to a cascade of cellular apoptosis and cerebral demyelination of the white matter in the brain tissue.[7,18] This neuropathy will affect vision if oxidative damage occurs along any part of the visual pathway, specifically in the occipital lobe.[19]

It is important to rule out other potential causes of these symptoms (diplopia, headaches, blurred vision and nausea) such as trauma, extraocular muscle (EOM) palsy, butane poisoning, mul-

tiple sclerosis, fatigue and migraines. **(Table 1)**

- Trauma is generally indicated as a differential diagnosis in blurred vision and diplopia. For cases with possible orbital damage, an X-ray is warranted to rule out any fractures that may cause muscle entrapment leading to diplopia. For other cases involving traumatic brain injury (TBI), computed tomography (CT) or magnetic resonance imaging (MRI) may be necessary to rule out any inflammation or structural damage causing the patient's symptoms. Nearly 75% of severe TBI cases present with acute neurological deficits and are most commonly seen with automotive injuries. Though specific numbers are unknown, it is also possible to see delayed diplopia and other mild visual disturbances following less severe trauma as well.[20] This usually is a secondary result of causes such as damage to intraocular structures (lens dislocation, vitreous tears or hemorrhages), damage to the visual pathway, or cranial nerve palsies.[20,21] In all cases of trauma, a detailed patient history is essential to help rule out or differentiate traumatic events and help guide management and treatment. Our patient reported no history of trauma, which quickly ruled this out.
- EOM palsy or a decompensated phoria can also be considered when patients present with vague symptoms of diplopia and headaches. While an EOM palsy presents slightly more often than a decompensated phoria (10% vs. 8%), proper testing can distinguish between the two differentials.[22] To differentiate a decompensated phoria, an assessment of vergence ranges and a binocular vision workup would be warranted. An EOM palsy can be caused by a mechanical blockage within the orbit secondary to thyroid eye disease or orbital tumors. These patients typically present with associated proptosis or exophthalmos, which would highlight the underlying cause, but an MRI or CT scan would be needed to differentiate between these conditions. It can also be caused by a neurological defect owing to complete or partial paresis of the extraocular muscles. The cause can be differentiated by the forced duction test or other tests, specifically the Parks 3-step or the red lens test can be used to identify the defective muscle(s). Because binocular vision testing and motility were within normal limits for the patient, this was ruled out as a differential.
- Butane poisoning exhibits similar symptoms to CO poisoning, including dizziness, headache and neurological depression. Symptoms vary depending on the severity and duration of intoxication.[23] It is important to differentiate from this due to the vast number of households that use gas as a heat source. According to the Centers for Disease Control, more than 50% of homes in the United States use a mixture of natural gas, butane and propane as the primary source of home energy.[24] In addition, butane is commonly used as a propellant for spray deodorant. A characteristic pungent odor can be associated with these gases to easily identify a leak. However, misuse and intentional abuse are very common causes of this poisoning and should also be considered during examination.[23] It is important to note that CO results from the burning of butane gas, and thus most cases of butane poisoning are differentiated from a thorough case history. Additional testing includes arterial blood gas and n-butane blood screens.
- Multiple sclerosis (MS) is an inflammatory, demyelinating central nervous system disease that typically presents in women age 20-45. It is associated with periods of remission between exacerbations. The signs and symptoms vary depending on the area affected in the brain or optic nerve and can often cause optic neuritis or ocular motility dysfunction.[25] Ocular signs and symptoms include visual impairment, optic neuritis, uveitis, papillitis, etc. A thorough history to evaluate any acute episodes of onset and remission of pain, visual field testing to determine any unilateral visual defects, and motility testing are helpful in differentiating early MS in patients. Areas of cortical blindness caused by CO toxicity can appear as occipital injury, white matter lesions and cerebral ischemia. These can sometimes be apparent through imaging techniques such as CT, MRI and single photon emission computed tomography (SPECT).[19,26] While the patient fits the age range for this particular differential, it was ruled out based on the unremarkable results of the tests performed on the patient.
- Giant cell arteritis (GCA) and

Table 1
Differential Diagnosis

	Age Range	Gender	Symptoms	Additional Tests
Trauma	Any	Any	Diplopia, visual disturbances, blurred vision, proptosis	X-rays/CT for orbit fractures, CT or MRI for inflammation or other structural damage
EOM Palsy	Any	Any	Diplopia, headaches, proptosis, exophthalmos	Forced duction, Parks 3-step, red lens, MRI, CT, X-ray
Butane Poisoning	Any	Any	Dizziness, headache, neurological depression	Arterial blood gases, n-butane blood screen
Multiple Sclerosis	20-45	Women	Visual impairment, optic neuritis, uveitis, papillitis	Visual field testing, MRI, CT, SPECT
Giant Cell Arteritis	50+	Men	Headaches, visual disturbances, reduced visual acuity, malaise	Erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), physical examination, temporal artery biopsy
Migraines	18-59	Women	Unilateral, extreme headaches, nausea, vomiting, and/or visual aura. Fatigue, dizziness	Physical examination

other ischemic optic neuropathies have been falsely diagnosed in the presentation of carbon monoxide poisoning. Both problems have similar symptoms, such as headaches and visual disturbances with grey patches, reduced visual acuity and malaise.[27] GCA testing includes physical examination, temporal artery biopsy, erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) blood tests. GCA typically presents in Scandinavian men older than 50, with incidence rising greatly with age. This very rarely affects people under the age of 50 and was ruled out for our patient.[28]

- Migraines are typically unilateral, extreme headaches and usually accompanied by nausea, vomiting and/or an occasional visual aura. Migraines can present with a prodrome that includes irritability, fatigue, dizziness, stiff muscles and other symptoms followed by subsequent auras, pain and headaches. They affect nearly 18% of women and 6% of men. Symptoms range from mild to disabling. Peak incidence of migraines is seen in women 30-39 years of age, but general high prevalence is reported between 18-59 years of age.[29] According to the International Headache Society Classification of Headaches, diagnosis of a migraine requires symptoms of nausea, vomiting or photophobia in addition to two of the following features: unilateral location, throbbing, worsening with routine activity or moderate to severe intensity.[30] A thorough history is required to classify a migraine, but was ruled out for our patient due to the negative history.

The literature describes several tests that can be used to diagnose CO poisoning. COHb levels can be tested to determine whether the patient has been exposed to carbon monoxide, but this test cannot be used to determine the severity of exposure or dictate prognosis. COHb levels also should not be used to dictate the extent of necessary treatment.[1] Other blood components and arterial blood gases are used to further illustrate the current status of CO poisoning within the bloodstream. Specifically, low arterial pH has been directly associated with increased mortality in carbon monoxide poisoning with a 30% mortality rate linked to an arterial pH of 7.25 or lower.[31] Arterial pH is lowered by COHb formation and deterioration in intracellular energy metabolism.[31] A calculated oxidative stress index (OSI) can also be very helpful in predicting the potential for delayed neurologic damage, so it is a good test to determine prognosis and dictate a specific treatment plan.[32] Finally, the literature also supports the use of positron emission tomography (PET) and SPECT scanning to determine which areas of the brain have become damaged or will show adverse effects even when MRI and CT imaging are within normal limits.[19] Unlike MRI or CT scans, these imaging studies both use radiolabeled, molecular components of a normal physiologic process that emit positrons or gamma rays when they decay. This allows quantitative imaging of a particular physiologic process, such as glucose metabolism in PET or cerebral blood flow in SPECT.[19] SPECT imaging with [99mTc]HMPAO of patients with visual loss secondary to carbon monoxide poisoning showed defects in cerebral blood flow within structures along the visual pathway.[9] Additionally, in patients with visual loss who were exposed to CO, fluorodeoxyglucose PET imaging showed deficits within the occipital region when MRIs were considered normal.[19] PET and SPECT imaging can be clinically valuable in determining the prognosis of patients affected by carbon monoxide because most MRI imaging fails to highlight damaged tissue.[19]

The standard treatment for CO exposure is considered to be oxygen therapy administered with different efficacies in different vehicles. The elimination of carbon monoxide from the body is accelerated by allowing oxygen to compete more effectively at hemoglobin binding sites. Using a face mask to administer high-flow, 100% oxygen, the half-life of carbon monoxide in the body can be decreased to 60-90 minutes.[2] A newer, more expensive alternative called hyperbaric oxygen therapy (HBO) has been found to reduce the half-life to 20-30 minutes if administered through multiple sessions at 3 atm.[2] This therapy involves a pressurized chamber that contains increased oxygen levels compared to normal atmospheric pressures.[2] Like other oxygen therapies, it is designed to administer higher levels of oxygen for inspiration, and its higher efficacy results in carbon monoxide being displaced more easily.[2] It is recommended to continue high-concentration oxygen therapy until the COHb level is below 5%.[13] Oxygen therapy also increases the oxygen reserve in the bloodstream and supplements the hypoxic parts of the body until equilibrium is reached.[2]

Intended audience for this teaching case report

This teaching case report is appropriate for all levels of learners. Recommended emphasis for first- and second-year students: application of basic science to explain clinical presentation, elements of thorough case history, test selection. Recommended emphasis for third-year students, fourth-year students and residents: the same as for first- and second-year students, with the addition of clinical application, assessment and management, and the optometrist's role on the healthcare team.

Learning objectives

- To describe common and uncommon ocular presentations found with acute, excess CO exposure
- To describe long-term effects of carbon monoxide poisoning
- To describe the general effect that carbon monoxide has on the body, eye and visual pathways, both immediate and delayed
- To describe retinal hypoxia and associated signs and symptoms
- To describe the physiological mechanism causing immediate vs. delayed damage and associated structures
- To identify key diagnostic tests for CO poisoning
- To describe treatment options for CO poisoning
- To apply critical thinking skills to the care of a patient (i.e., know how to develop differential diagnoses and know what tests can rule out each possible cause)
- To understand the role and re-

sponsibilities of the primary care optometrist in the management of a patient with symptoms suggestive of carbon monoxide poisoning (i.e., know how to take a good case history and know what questions to ask relevant to CO poisoning and how to provide proper patient education)

- To know which healthcare professionals to make a referral to depending on cause and extent of CO exposure

Key concepts

- The body's response to acute hypoxic events, including ocular and systemic symptomatology
- Testing and procedures used for the differential diagnosis of CO poisoning
- Events and risk factors leading to carbon monoxide poisoning
- The pathophysiology of carbon monoxide on the body/eye/visual system
- Treatment of CO poisoning

Discussion topics

- Ocular anatomy:
  - retinal layers
  - retinal blood supply
  - sources of energy
    - metabolism of the retinal layers
- Neurological anatomy:
  - occipital lobe
    - anatomy of the occipital lobe including blood supply, visual pathways, possible visual field defects
    - function of the occipital lobe
- Regarding carbon monoxide poisoning
  - environmental, social and demographic factors and the risk for CO poisoning
  - common sources of carbon monoxide exposure
  - carbon monoxide poisoning vs. other gas poisoning
  - ocular findings associated with acute hypoxic events
  - ocular and medical history (i.e., how to take a history on a patient exposed to CO)
  - ocular findings
  - differential diagnosis
    - trauma
    - EOM palsy
    - butane poisoning
    - multiple sclerosis
    - giant cell arteritis
    - migraines
  - visual fields (i.e., differentiate between a pre-chiasmal, chiasmal and post-chiasmal defect)
  - laboratory testing
  - treatment options
    - standard treatment options available
    - patient education on indications and complications of treatment
    - devices for detection of carbon monoxide
    - long-term effects of carbon monoxide poisoning
    - necessity and type of referrals
  - patient education on long-term effects (i.e., population at greatest risk, long-term sequelae, proper referral for long-term management)

Discussion

Case history

Upon initial presentation, the patient complained of vague and general symptoms of blurriness and double vision that had resolved by the time she arrived at the clinic. She also mentioned episodes of headaches, malaise and nausea in correspondence with her ocular symptoms. The most common symptom associated with CO poisoning is a headache, but other visual symptoms such as photophobia, blurred vision and diplopia have been documented as well.[33] With cases of carbon monoxide exposure, it is important to take a detailed and thorough ocular and medical history in order to properly diagnose and identify the cause of exposure. The clinician should ask questions regarding the specific time and duration of the symptoms in addition to identifying any specific palliative or provocative factors involved. In this case, the symptoms were exacerbated while the patient was in her apartment and improved after she would leave for some time. It is also warranted to ask what the patient was doing when she noticed the symptoms. She stated that her symptoms peaked when she went running despite the fact that she was physically fit and a perpetual runner. It is shown that carbon monoxide poisoning can manifest at lower levels of exposure during exercise.[5] Particularly when symptoms are seemingly unusual or vague, it also is important to ask if anything has changed in the patient's personal, social or medical history within the past few months. In this case, the patient was able to remember that the furnace in her apartment complex had malfunctioned within the past week. The symptoms of vision loss associated with CO poisoning are either absent or very vague in most cases, but without a proper diagnosis and treatment the long-term effects to vision can be catastrophic. The clinician must rely on thorough history-taking and diagnostic tests to reach a diagnosis.

Confirmation of diagnosis

There are several diagnostic tests that can be used with a suggestive case history or with vague symptoms where a diagnosis is unclear. Measurement of COHb levels is the standard of care when carbon monoxide exposure is suspected. This helps to determine whether the individual has been exposed to carbon monoxide, but it is unable to determine severity of exposure or prognosis.[1] It only indicates whether the patient has been exposed within the time frame it takes to eliminate carbon monoxide (COHb) from the bloodstream, and any concentration level above 2-3% is considered abnormally elevated.[13,11] The COHb level in this patient was 0.8%, which is within the normal range and not enough to cause symptoms. However, the time frame between testing and exposure must be taken into consideration. This patient was initially seen at 1:10 p.m., and blood work was performed at 4:46 p.m. Additionally, she had not spent a considerable amount of time near the

source of exposure prior to blood testing because she had not slept at her apartment for more than 24 hours. This measurement can give a false negative if there is a delay of more than 12 hours between testing and the last exposure as in this case because CO levels in the blood decrease exponentially after the patient is removed from the source.[13,32] The improvement in symptoms after exposure is ceased is an obvious indication of CO poisoning, and the delay in COHb testing should be considered as the reason for a false negative in this case.

However, carbon monoxide toxicity is also considered a diagnosis of exclusion. Other testing must be administered to rule out differentials and other systemic etiologies. In this case, the patient presented with previous episodes of blurry vision and diplopia. Subjective refraction revealed a mild amount of uncorrected refractive error, but the fact that the patient was familiar with being habitually uncorrected implies that her episode of blurry vision was acutely severe and had resolved by the time of the exam. The patient's intermittent blurry vision was also assessed by performing NRA, PRA and FCC. This accommodative testing was performed to determine the potential for latent hyperopia and confirm accuracy of the subjective refraction. Humphrey visual field testing was utilized to further analyze the patient's unspecified loss of vision. Specifically, it is important to know that the patient was not experiencing any peripheral vision loss or focal loss of sensitivity within her visual field.

When a patient presents with episodes of double vision, it is important to perform a preliminary binocular vision workup and extraocular muscle assessment to rule out any ocular cause of diplopia. In this case, the patient's binocular vision status was considered within normal limits, as defined by fixation disparity and phoria testing. Also, no palsy or muscle restriction was noted. If the diplopia had been unresolved at the time of the exam, it would have been prudent to determine comitancy and severity. This additional testing sufficed to rule out an ocular cause for the complaint of episodic, intermittent diplopia.

It is also important to order other blood and ancillary testing to aid in evaluating possible systemic etiologies. In this case, CBC with differential and arterial blood gases were ordered to give normal values with the exception of an elevated arterial pH. This systemic alkalosis could be an indication of the body's adaption mechanism to reduce the adverse effects of carbon monoxide within the body. Measuring other blood components or ordering an electrocardiogram (ECG) or chest X-ray would be other ways to monitor the cardiovascular side effects associated with carbon monoxide exposure. Other testing that could have provided more information about prognosis would be a calculated OSI value and PET and SPECT imaging. These tests would have been required if other neurological symptoms had persisted because their results indicate the extent of any delayed neurologic injury.

Management and treatment

The initial treatment for acute CO poisoning is identifying and quickly removing the source of exposure. Because CO is removed primarily via pulmonary circulation, treatment options are directed toward increasing oxygenation to decrease the half-life of CO within the body. Mild to moderate exposure can be treated using high-flow, 100% oxygen in isobaric conditions. This has been shown to decrease COHb half-life from 300 to 90 minutes.[2] In more severe cases without improvement, hospitalization and HBO may be required. This method can decrease COHb half-life to just 30 minutes within the body, but facilities are limited within the country.[2] Special attention must also be given for children and pregnant women due to their higher oxygen requirements and greater risk for hypoxic damage. Because CO bound to fetal hemoglobin has a longer half-life, it is essential to initiate treatment immediately for these patients.[11] In patients at risk for heart disease, it is also advisable to obtain an ECG to monitor for any possible cardiac ischemia.[34]

Long-term prognosis following CO poisoning can vary depending on the severity and duration of intoxication. Once maximal therapy is implemented, a physical assessment of overall health should be performed. Though uncommon, it is possible to see delayed neurocognitive function in certain patients, so a neurological evaluation should also be done.[35] Our patient presented with very unspecific symptoms associated with her CO exposure, so it was important to educate her on the possibility of these adverse effects in neurocognitive and psychological function.[4,35] COHb levels should be monitored regularly over time, if possible, until levels are normal. Patients should be thoroughly educated on risk factors, common sources contributing to CO poisoning, and early clinical findings to ensure they do not have a repeat event. Preventative measures including CO detectors and routine furnace maintenance should be taken.

Cases of intentional poisoning, though not as common, should be handled very cautiously. Most suicide attempts by carbon monoxide are seen in middle-aged men and typically in rural regions.[36] A variety of social problems have also been correlated with the incidence of suicide by CO poisoning, so the support of family and friends is essential during the recovery period.(36) These patients along with their support network of family and friends should be educated on the symptomatology, and patients should undergo psychological evaluation as soon as possible to determine the potential risk for suicide. They should be monitored very closely by their primary care physician and psychiatrist in order to receive proper treatment.[36]

Conclusion

This case demonstrates the importance of a thorough patient history and comprehensive examination in diagnosing cases of an uncommon etiology. Rather than diagnosing from a particular finding, this particular case has shown that diligently ruling out differential etiologies and asking certain questions during an exam can lead to a proper and successful diagnosis. Cases such as this are rarely seen in an optometric setting, as they generally are caught in an emergency room or by a family doctor. However, this case highlights the need for eyecare professionals to recognize the possible ocular, systemic and neurological effects of carbon monoxide poisoning and the impending, long-

term risk factors. Mild, acute CO poisoning presents with general headache, malaise and blurred vision, and rarely diplopia. These particular symptoms must be correlated and diagnosed early in order to prevent chronic problems for patients. Proper education about long-term effects, elimination of the cause, and integration of preventative measures for future incidences must be implemented for patient safety.

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