A Comprehensive Surgical Curriculum Reduced Intra-operative Complication Rates of Resident-performed Cataract Surgeries

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OBJECTIVES: To evaluate the impact of a comprehensive cataract surgery curriculum on the incidence of intraoperative complications.

DESIGN: We retrospectively compared the total number of cataract surgeries that the residents performed in all of the teaching sites, and the incidences of intraoperative complications (anterior capsule tear, posterior capsule rent, vitreous loss, anterior vitrectomy, zonular dialysis, iris trauma, hemorrhage, dropped lens fragment, corneal wound burn, incorrect intraocular lens) for the surgeries performed at Massachusetts Eye & Ear by residents in the pre-intervention group (residents graduating in 2004 and 2005), before the implementation of a surgical curriculum, and the residents in the post-intervention group (residents graduating in 2014 and 2015).

SETTING: Ophthalmology residency program at a major academic institution.

PARTICIPANTS: Residents graduating in 2004, 2005, 2014, and 2015.

RESULTS: We reviewed 4373 charts. 2086 of those surgeries were performed at Massachusetts Eye & Ear. The incidence of posterior capsule rent/vitreous loss/anterior vitrectomy was lower in the post-intervention group (1.4% versus 7.7%, $p < 0.0001$). Other complications were also lower in the post-intervention group.

CONCLUSIONS: Implementation of a comprehensive cataract surgery curriculum focusing on pre-operative, intra-operative and post-operative interventions, with an emphasis on patient outcomes resulted in a decrease in the rate of intraoperative complications. (J Surg Ed 76:150–157. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: curriculum, education, residents, ophthalmology, eye, surgery

COMPETENCIES: Patient Care, Medical Knowledge, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Recent trends in health care have emphasized patient-centered care and monitoring of outcomes. These trends have affected all of the medical specialties, including ophthalmology. Most patients who underwent cataract surgery expect visual improvement and an accurate refractive outcome. Concurrently, residency programs are required to improve patient safety and provide high quality patient care without compromising their educational mission. These mandates are driving residency programs to seek new and better ways to enhance

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resident surgical education while maintaining high standards of quality of care.

Traditionally, surgical teaching has centered on the concept of graded responsibility and exposure to a high volume of cases.[1] Recently, surgical curricula that utilize models, simulators, and wet labs have been developed to teach surgical skills before performing surgery on patients.[2–5] In addition, cognitive learning and motor skill acquisition are evaluated during the surgical skills labs.[6–11] Because of the specific challenges of ophthalmic surgery training, cataract surgery educators are increasingly interested in standardizing and improving the curriculum to teach cataract surgery.[12–16]

Since 2005, major changes have been made to the cataract surgery training program at Massachusetts Eye and Ear (MEE), the sponsoring institution of the Harvard Medical School Residency Program in Ophthalmology. A surgical curriculum was created and an initiative was launched to improve patient outcomes and the quality of surgical teaching. At the conclusion of each academic year after implementation of the curriculum, feedback from residents and faculty was collected. In response to this feedback, the curriculum was enhanced each subsequent year.

We hypothesized that implementation of a comprehensive, longitudinal cataract surgery curriculum that emphasized pre-operating room (OR) training and patient outcomes would lower the rate of intraoperative complications in resident-performed cataract surgeries. To measure the effects of implementation of this curriculum, we compared two groups of residents: residents who graduated in 2004 and 2005, before implementation of any surgical curriculum, and residents who graduated in 2014 and 2015, after the curriculum was implemented. For these two groups, we compared the intra-operative complication rates for the surgeries performed at MEE.

METHODS

The Curriculum

The curriculum was divided into pre-OR, intra-OR, and post-OR training interventions. The elements of this curriculum were introduced in stages between 2005 and 2014. The training interventions and years of implementation are outlined in Table 1.

The pre-operative training interventions included various skills-transfer and evaluation methods in the surgical training lab, pre-operative didactic and case-based education, and participation in pre-operative planning. The intra-operative interventions included a structured introduction to cataract surgery, supervision by experienced cataract surgery teachers, and immediate feedback and evaluation of performance. The post-operative interventions included participation in post-operative care, analysis of outcomes, and participation in cataract morbidity and mortality conferences.

The core components of the curriculum were administered to residents at MEE, the primary site of the Harvard Ophthalmology Residency Training Program. The surgical training laboratory and a core group of surgical teaching faculty who were engaged in the curriculum were located at MEE. Residents in the Harvard Ophthalmology Residency Training Program have opportunities to serve as primary surgeons at several teaching hospitals including MEE, the Boston Veterans Affairs Hospital, the Togus Maine Veterans Affairs Hospital, and the Beth Israel Deaconess Medical Center. Although the curriculum was primarily implemented at MEE, we expected that it would also positively impact resident preparation and surgical performance at the other teaching sites.

Comparison of Surgical Outcomes for Residents Graduating in 2004 to 2005 and 2014 to 2015

Cases in which residents were the primary surgeons were identified by reviewing the Accreditation Council for Graduate Medical Education (ACGME) surgical logs for 2004, 2005, 2014, and 2015. Exclusion criteria included cataract surgeries in which residents were not the primary surgeons and cataract surgeries performed for eye trauma cases. We performed a retrospective review of the medical records of patients whose cataract surgeries were performed by residents of the Harvard Ophthalmology Residency Training Program who graduated in 2004, 2005, 2014, and 2015. Residents who graduated in 2004 to 2005 represent the pre-curriculum implementation period (pre-intervention group) and residents who graduated in 2014 to 2015 represent the post-curriculum implementation period (post-intervention group). The operative notes for these resident cases were reviewed for intra-operative complications. The faculty who teach surgery at MEE were engaged in the curriculum and delivered consistent intra-operative teaching and supervision. This study was exempt from review by the MEE Institutional Review Board.

Outcome Measures

The primary outcome measures were intraoperative complications including posterior capsule rent, anterior capsule tear, vitreous loss, anterior vitrectomy, zonular dialysis, corneal wound burn, dropped lens fragment, incorrect intraocular lens, hemorrhage, and iris trauma. The medical records that were reviewed

TABLE 1. A Longitudinal Cataract Surgery Curriculum for Ophthalmology Residents

Phase of Patient Care	Teaching Method	Implementation	Year of Implementation
Pre-OR	Technical skills practice in the surgical training laboratory	• A surgical skills training laboratory adjacent to the resident room was always available to the residents. Independent practice was expected throughout all three years of training.	2009
		• A group of eight core wet lab faculty from multiple subspecialties proctored residents, one-on-one, throughout the year. Skills in different specialty area were taught. Each resident received at least four 90-min one-on-one teaching sessions.	2009
		• Core wet lab faculty completed verbal and written assessments of residents at the completion of the sessions using the Global Rating Assessment of Skills in Intraocular Surgery (GRASIS) form.[27]	2009
		• Several clinical rotations included weekly or bi-weekly faculty-proctored wet lab sessions.	2009
	Simulation	• Simulations including EyeSi (EYESI® Ophthalmosurgical Simulator, VRmagic GmbH, Mannheim, Germany), animal eyes, and the Kitaro cataract training system (Kitaro Dry Lab kits, FCI Ophthalmics Inc) were incorporated in the surgical training laboratory to develop technical skills.	2009
		• All of the residents were given access to an on-line teaching program that simulates the cognitive skills and decision-making required for cataract surgery[33] (Massachusetts Eye & Ear Cataract Master™).	2012
	Graduated progression from direct to indirect supervision during pre-operative planning	• PGY-2 residents received case-based teaching in each cataract OR on a six-week rotation in which a faculty member reviewed pre-operative plans including patient selection, refractive target selection, interpretation of biometry and topography, and intraocular lens selection.	2014
		• PGY-3 residents received six one-on-one case-based teaching sessions with a faculty cataract surgeon that focused on these same elements with the resident actively engaged in pre-operative decision making.	2013
		• PGY-4 residents prepared pre-operative patient plans including review of testing and intraocular lens selection on all major cataract surgery rotations. A faculty member then reviewed the plan with the resident and gave feedback.	2011
	Group-based teaching	• PGY-3 residents attended the Harvard Medical School Intensive Cataract Course for 2nd year residents that consists of didactic lectures and wet lab sessions focused on cataract surgery teaching to prepare residents for their senior year of residency	2005
	Quality/Outcomes measurement	• PGY-4 residents completed a cataract surgery outcomes database form that collects pre-operative and intra-operative information that is a key component of the MEE quality initiative to monitor cataract outcomes (Cataract Surgery Database Form).	2011
Intra-OR	Direct supervision by experienced cataract surgery teachers	• All cataract surgeries were supervised by experienced cataract surgery teachers.	Pre-existing
		• The cataract surgery teaching faculty used a methodology that closely mirrored the Briefing-Intraoperative Teaching-Debriefing model.[7,15]	
	Stepwise introduction to cataract surgery	• PGY-2 residents were introduced to cataract surgery in a stepwise manner that allowed them to practice the surgical steps in a repeated, deliberate manner before performing an entire surgery.[19]	2009

(continued)

TABLE 1 (*CONTINUED*)

Phase of Patient Care	Teaching Method	Implementation	Year of Implementation
	Emphasis on patient safety	• Attending surgeons had a low threshold to "take over" a surgical case if there were a complication or suspicion of a complication, if a resident had attempted a surgical maneuver several times without success, or if there were visualization challenges. Attending surgeons "handed back" the case to allow the resident to continue to serve as primary surgeon, as appropriate.	
Post-OR	Immediate feedback/ assessment	• Faculty gave verbal feedback at the end of each case, and completed a GRASIS (Global Rating Assessment of Skills in Intraocular Surgery) form[27] at the end of each OR session that was reviewed with the resident.	2009
		• The cataract surgery database form that was completed pre-operatively was updated with the intra-operative data and complications.	2011
	Quality/Outcomes	• Residents were given their individual cataract surgery complication rates bi-annually including percent of vitreous loss and percent of cases within 1 Diopter of the refractive target.	2014
	Case based review	• Didactics in the management of cataract patients were supplemented with quarterly cataract surgery complication conferences in which residents reviewed cataract surgery complications with cataract surgery teaching faculty to identify factors that may have contributed to the complications and possible ways to prevent and manage the complications in the future.	2008

consisted of paper and electronic charts. The number of unobtainable charts, missing operative notes, and invalid medical record numbers were recorded for each year analyzed.

For our statistical analysis, posterior capsule tear, vitreous loss and anterior vitrectomy were considered one complication as they reflected the continuum of one intra-operative event.

Statistical Analysis

Data are presented as median (interquartile range) or n (%).The Fisher's exact test was used to compare incidences of complications for residents in the pre-intervention (2004 and 2005 graduates) and post-intervention (2014 and 2015 graduates) groups. Poisson regression with robust error variance was used to calculate risk ratios and 95% confidence intervals for the incidences of complications between the two groups.[17] All of the tests were two-sided and p-values <0.05 were considered statistically significant.

RESULTS

We reviewed 4373 charts of patients who had cataract surgeries performed by residents who graduated in 2004, 2005, 2014, and 2015. In 2086 of the cases, the residents were the primary surgeons and were supervised by a cataract surgeon employed by MEE.

Fifty-six cases were excluded from the class of 2004, 55 cases were excluded from the class of 2005, 40 cases were excluded from the class of 2014, and 18 cases were excluded from the class of 2015 because the operative notes could not be found based on the case number logged by the resident in the ACGME case log system. All of the surgeries performed by one resident in the class of 2005 were excluded because the resident entered inaccurate patient identifiers for the majority of the logged cases and the operative reports could not be located. The results are presented in Tables 2 and 3.

The median number of surgeries performed by residents in the pre-intervention group was 120 (interquartile range 107-138). The median number of surgeries performed by residents in the post-intervention group was 175 (interquartile range 159-200).

The incidence of posterior capsule rent/vitreous loss/anterior vitrectomy was significantly lower in the post-intervention group than in the pre-intervention group (1.4% versus 7.7%; $p < 0.0001$; Table 2). The risk of posterior capsule tear/vitreous loss/anterior vitrectomy was 5.6 times lower in the post-intervention group than in

TABLE 2. Incidences of Complications in the Pre-intervention and Post-intervention Groups

Complication	Pre-intervention N = 804	Post-intervention N = 1282	p
Posterior capsule rent/vitreous loss/anterior vitrectomy	62 (7.7)	18 (1.4)	<0.0001
Anterior capsule tear	18 (2.2)	11 (0.9)	0.009
Corneal wound burn	6 (0.8)	0 (0.0)	0.003
Dropped lens fragment	7 (0.9)	2 (0.2)	0.03
Hemorrhage	2 (0.3)	0 (0.0)	0.15
Iris trauma	9 (1.1)	1 (0.1)	0.001
Zonular dialysis	13 (1.6)	8 (0.6)	0.03

Data presented as n (%).
N: number of surgeries.

TABLE 3. Relative Risk of Complications in the Post-intervention Compared to the Pre-intervention Group

	RR (95% CI)	p
Posterior capsule rent/ vitreous loss/anterior vitrectomy	0.18 (0.11-0.31)	<0.0001
Anterior capsule tear	0.38 (0.16-0.90)	0.03
Dropped lens fragment	0.18 (0.04-0.86)	0.03
Iris trauma	0.07 (0.01-0.59)	0.01
Zonular dialysis	0.39 (0.12-1.26)	0.11

RR: relative risk; CI: Confidence interval.

the pre-intervention group (risk ratios: 0.18; 95% confidence intervals: 0.11-0.31; $p < 0.0001$; Table 3). In addition, the incidences of anterior capsule tear, iris trauma, corneal wound burn, dropped lens fragment, and zonular dialysis were statistically lower in the post-intervention classes. The incidence of hemorrhage was also lower in the post-intervention group, but not statistically significant. There were no incorrect intraocular lens cases.

DISCUSSION

We found a significant reduction in the incidence of posterior capsule tear/ vitreous loss/ anterior vitrectomy after implementation of a longitudinal cataract surgery training program that focused on pre-OR, intra-OR, and post-OR training, and emphasized patient safety and outcomes.

The rate of posterior capsule tear with or without vitreous loss and anterior vitrectomy was 1.4% for the graduating classes of 2014 and 2015, which is among the lowest reported in the literature for cases performed by residents. A wide range of rates of complications for cataract surgeries performed by ophthalmology residents have been reported.[15,18,19,20,21,22,23,24,25,26] A recent literature review of complication rates from resident-performed cataract surgeries reported that the rate of vitreous loss ranged from 1.8 to 19% and that the rate of posterior capsule tear ranged from 0.6 to 18%.[25] Studies of resident-performed cataract surgery complication rates are not easy to compare due to variability in number of patients, procedures performed, types of complications included, case complexity, and method of defining and reporting complications. For example, some studies reported overall complication rates, whereas other studies reported rates of specific complications such as posterior capsule tear or vitreous loss. In some studies, posterior capsule tear with vitreous loss was counted as one complication, and in other studies they were considered as two different complications. In addition, complication rates vary with case complexity[18,19], the experience of the resident[14,15], the experience of the attending surgeon[20], and the degree of supervision by the attending surgeon.[23]

Rogers et al. found that the introduction of a structured surgical curriculum for cataract surgery training was associated with a reduced rate of sentinel complications (posterior capsule tear with or without vitreous loss and vitreous loss) in surgeries performed by residents.[12] Our study which implemented comprehensive pre-operative, intra-operative and post-operative curricula for all 3 years of residency that included didactic sessions, wet lab practice, simulation and structured OR experiences, supports and expands the findings by Rogers et al. In addition, our study described specific methods used to enhance, report, and monitor patient safety and outcomes, both in the OR by establishing a culture of low threshold to "take over" and "hand back" cases, and during the post-operative period with verbal feedback by the attending supervisor at the end of each case and review of complications caused by residents in didactic conferences.

The demonstration of improved patient outcomes is the gold standard for this type of educational intervention. Although it is challenging to control for the complexities of residency experience over the 3 years of

training during which pre-operative, intra-operative and post-operative curricula were utilized, we demonstrated that our intervention achieved level 4 of Kirkpatrick's model, which evaluates training programs on four levels: reaction, learning, behavior, and results. To reach level 4, an educational activity must result in measurable improved outcomes.[28]

Nevertheless, our study has some limitations and confounders. All of the surgeries were performed at a single institution and residency program, which limits the applicability of our results to other programs. Moreover, we measured intra-operative complication rates for surgeries performed at MEE, but excluded surgeries performed by the same residents during rotations at other sites, because the data available at the other teaching sites were incomplete, and because implementation of the curriculum and related teaching outlined above occurred at MEE. Although there is no way to definitively address this point without data, the feedback given to us from these teaching sites aligns with the observations and data from the MEE cases.

In addition, more cases were excluded from the pre-intervention group than from the post-intervention group because operative reports could not be found and this exclusion may have led to selection bias.

In our study, the number of surgeries performed by residents increased from a median of 120 cases (interquartile range 107-138) in the pre-curriculum to a median of 175 (interquartile range 159-200) in the post-curriculum period. The continuous increase in resident surgical volume is a universal trend in US ophthalmology programs as reported by the ACGME, and this fact could have contributed to the lower complication rate observed in the post-intervention group.[29] As previously reported in the literature, resident experience from increased surgical volume may be associated with lower complication rates.[14,15] In addition, the variable degree of attending "take over" of the case was impossible to assess in this retrospective study. These confounders would be interesting points for future studies to address.

In addition, during the 11 years between 2004 and 2015, there were advances in technology and equipment for cataract surgery that may have contributed to the improved patient outcomes. The most important advancement was that the residents in the "post-intervention" classes used the Alcon Infiniti system, whereas residents in the "pre-intervention" classes used the Alcon Series 20,000 Legacy phacoemulsifier (Fort Worth, TX). Furthermore, the post-intervention group used newer operating microscopes, which may have enhanced intraoperative visualization and improved clinical outcomes. For example, the decrease in the incidence of corneal wound burn could be attributed to the newer phacoemulsification technology that prevents ultrasound initiation before aspiration and allows for improved fluidic cooling.

Recently, there has been a growing emphasis on monitoring outcomes that may have contributed to the lower complication rate that we observed in the post-intervention group. Beginning in 2014, residents were given their outcomes data, which could have led to more careful reporting or possible under-reporting of cases in which residents were the primary surgeons. Also, residents may have spent more time practicing in the wet lab and may have been more careful in the OR because they knew that their results were being monitored and saved in their permanent residency records. Outcomes monitoring may have also made the attendings more likely to intervene intra-operatively when the residents encountered difficulties, to prevent more serious complications.

Finally, our study did not analyze the effects of specific aspects of our curriculum on the rates of complications from resident-performed surgeries, but rather examined broadly the effect of implementation of a comprehensive curriculum. Studies have been published on the value of specific curriculum components, some by our program. For example, Kloek et al. showed the effect of stepwise introduction to cataract surgery on the preparedness of residents for their senior year.[13] Henderson et al. evaluated the effect of the Virtual Mentor, a cognitive computer simulation, on teaching the hydrodissection step.[30] McCannel et al. found that capsulorrhexis complications decreased after the implementation of an intensive capsulorrhexis simulator training program.[3] Dang et al. evaluated whether an Online Surgical Outcome Database tool improved resident performance monitoring (complication rate and refractive outcomes) and cataract surgery education.[31] Nevertheless, additional studies are needed to assess the utility of specific components of surgical curricula. In our study, we could not evaluate the impact of individual components of our curriculum because several of them were implemented at approximately the same time; thus, we selected the 2004 to 2005 classes and the 2014 to 2015 classes for comparison. The 2014 and 2015 classes experienced all aspects of the comprehensive curriculum during their 3 years of residency training. In addition, the core wet lab faculty and attending surgeons for the 2014 to 2015 classes had several years of experience with the curriculum and were past the "transition" phase.

Given the limitations and challenges inherent to a retrospective analysis of a longitudinal educational intervention, our data suggest that a cataract surgery training curriculum that spans the 3 years of ophthalmology residency training, that focuses on the three phases of operative care, and that emphasizes patient safety yields favorable outcomes in cataract surgeries performed by residents. In addition, we anecdotally observed other

benefits of the curriculum, which we believe will equip residents with practical skills for their future careers, including improved awareness of patient safety and outcomes monitoring, as well as an understanding of how to approach learning and incorporation of a new surgical procedure or technological advancement into one's practice in the future.

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REFERENCES

1. Reznick R, MacRae H. Teaching surgical skills-changes in the wind. *N Engl J Med*. 2006;355:2664–2669.
2. Grantcharov TP, Kristiansen VB, Bendix J, Bardram L, Rosenberg J, Funch-Jensen P. Randomized clinical trial of virtual reality simulation for laparoscopic skills training. *Br J Surg*. 2004;91:146–150.
3. McCannel CA, Reed DC, Goldman DR. Ophthalmic surgery simulator training improves resident performance of capsulorhexis in the operating room. *Ophthalmology*. 2013;120(12):2456–2461.
4. Khunger N, Kathuria S. Mastering surgical skills through simulation-based learning: practice makes one perfect. *J Cutan Aesthet Surg*. 2016;9(1):27–31.
5. Beyer-Berjot L, Aggarwal R. Toward technology-supported surgical training: the potential of virtual simulators in laparoscopic surgery. *Scand J Surg*. 2013;102(4):221–226.
6. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. *Acad Med*. 2015;90(11):1471–1486.
7. Benjamin L, Bloom P, Darzi A, Sullivan P. Skills acquisition and assessment after a microsurgical course for ophthalmology residents. *Ophthalmology*. 2009;116:257–262.
8. Grantcharov TP, Reznick RK. Teaching procedural skills. *BMJ*. 2008;336:1129–1131.
9. Francis DO, Eavey RD, Wright HV, Sinard RJ. Incorporating postoperative debriefing into surgical education. *J Surg Educ*. 2016;73(3):448–452.
10. Leung Y, Salfinger S, Mercer A. The positive impact of structured teaching in the operating room. *Aust N Z J Obstet Gynaecol*. 2015;55(6):601–605.
11. Bonrath EM, Dedy NJ, Gordon LE, Grantcharov TP. Comprehensive surgical coaching enhances surgical skill in the operating room: a randomized controlled trial. *Ann Surg*. 2015;262(2):205–212.
12. Rogers GM, Oetting TA, Lee AG, et al. Impact of a structured surgical curriculum on ophthalmic resident cataract surgery complication rates. *J Cataract Refract Surg*. 2009;35:1956–1960.
13. Kloek CE, Borboli-Gerogiannis S, Chang K, et al. A broadly applicable surgical teaching method: evaluation of a stepwise introduction to cataract surgery. *J Surg Educ*. 2014;71(2):169–175.
14. Randleman JB, Wolfe JD, Woodward M, Lynn MJ, Cherwek DH, Srivastava SK. The resident surgeon phacoemulsification learning curve. *Arch Ophthalmol*. 2007;125:1215–1219.
15. Taravella MJ, Davidson R, Erlanger M, Guiton G, Gregory D. Characterizing the learning curve in phacoemulsification. *J Cataract Refract Surg*. 2011;37:1069–1075.
16. Lotfipour M, Rolius R, Lehman EB, Pantanelli SM, Scott IU. Trends in cataract surgery training curricula. *J Cataract Refract Surg*. 2017;43(1):49–53.
17. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004;159:702–706.
18. Rutar T, Porco TC, Naseri A. Risk factors for intraoperative complications in resident-performed phacoemulsification surgery. *Ophthalmology*. 2009;116:431–436.
19. Blomquist Preston H. M.D., Morales ME, Tong L, Ahn C. Risk factors for vitreous complications in resident-performed phacoemulsification surgery. *J Cataract Refract Surg*. 2012;38(2):208–214.
20. Puri S, Kiely AE, Wang J, Woodfield AS, Ramanathan S, Sikder S. Comparing resident cataract surgery outcomes under novice versus experienced attending supervision. *Clin Ophthalmol*. 2015;9:1675–1681.
21. Bhagat N, Nissirios N, Potdevin L, et al. Complications in resident-performed phacoemulsification cataract surgery at New Jersey Medical School. *Br J Ophthalmol*. 2007;91:1315–1317.
22. Quillen DA, Phipps SJ. Visual outcomes and incidence of vitreous loss for residents performing phacoemulsification without prior planned extracapsular cataract extraction experience. *Am J Ophthalmol*. 2003 May;135(5):732–733.

23. Hashemi H, Mohammadpour M, Jabbarvand M, Nezamdoost Z, Ghadimi H. Incidence of and risk factors for vitreous loss in resident-performed phacoemulsification surgery. *J Cataract Refract Surg*. 2013;39(9):1377–1382.

24. Woodfield AS, Gower Cassard SD, Ramanthan S. Intraoperative phacoemulsification complication rates of second- and third-year ophthalmology residents: a 5-year comparison. *Ophthalmology*. 2011;118:954–958.

25. Payal RP, Gonzalez-Gonzalez LA, Chen X, et al. Outcomes of cataract surgery with residents as primary surgeons in the Veterans Affairs Healthcare System. *J Cataract Refract Surg*. 2016;42:370–384.

26. Briszi A, Prahs P, Hillenkamp J, Helbig H, Herrmann W. Complication rate and risk factors for intraoperative complications in resident performed phacoemulsification surgery. *Graefes Arch Clin Exp Ophthalmol.* 2012;250:1315–1320.

27. Cremers SL, Lora AN, Ferrufino-Ponce ZK. Global rating assessment of skills in intraocular surgery (GRASIS). *Ophthalmology*. 2005;112:1655–1660.

28. Kirkpatrick DL, Kirkpatrick JD. Evaluating Training Programs: The Four Levels. 3rd ed. San Francisco, CA: Berrett-Koehler; 2006.

29. Accreditation Council for Graduate Medical Education (ACGME). Ophthalmology Case Logs: National Data Report. 2010-2017, http://www.acgme.org/Data-Collection-Systems/Case-Logs-Statistical-Reports [Accessed June 4, 2018]

30. Henderson BA, Kim JY, Golnik KC, et al. Evaluation of the virtual mentor cataract training program. *Ophthalmology*. 2010;117(2):253–258.

31. Dang S, Winkler K, Kromrei H, Juzych M. Online surgical outcome database to improve resident cataract surgery performance. *J Grad Med Educ*. 2014;6(2):374–375.