

# The Iowa Ophthalmology Wet Laboratory Curriculum for Teaching and Assessing Cataract Surgical Competency

Andrew G. Lee, MD,<sup>1,2</sup> Emily Greenlee, MD,<sup>1,3</sup> Thomas A. Oetting, MS, MD,<sup>1,3</sup> Hilary A. Beaver, MD,<sup>1</sup> A. Tim Johnson, MD, PhD,<sup>1</sup> H. Culver Boldt, MD,<sup>1</sup> Michael Abramoff, MD, PhD,<sup>1,4</sup> Richard Olson, MD,<sup>1</sup> Keith Carter, MD<sup>1</sup>

**Purpose:** To describe an ophthalmology wet laboratory (OWL) curriculum for residents in training.

**Methods:** Systematic literature review and selection of best practices for use in the OWL learning plan from a single academic ophthalmology program.

**Results:** A pretest and posttest of cognitive skills, objective wet laboratory structured assessment of skill and technique, and summative global evaluation form were developed as part of a systematic OWL curriculum.

**Conclusion:** The Iowa OWL curriculum may form the basis for successfully utilizing the wet laboratory to teach and assess aspects of resident surgical competence in cataract surgery. *Ophthalmology* 2007;xx:xxx  
© 2007 by the American Academy of Ophthalmology.

The Accreditation Council for Graduate Medical Education (ACGME) has mandated that all residency training programs teach and assess 6 general competencies.<sup>1,2</sup> The American Board of Ophthalmology has recommended that a seventh competency in surgery be required. At the time of writing of this article, the ACGME still includes surgery in the patient care competency. Teaching and assessing resident surgical performance in ophthalmology pose special problems. First, the performance of a technique that has not been mastered by the resident surgeon in a live patient produces unique ethical issues in terms of disclosure, informed consent, and faculty supervision. In addition, the number of cases available for residents is increasingly under threat due to external constraints on supervising faculty and operating room time and efficiency. Many residency programs have turned to outsourcing of cataract surgical training to out-of-state or out-of-country institutions. Rowden and Krishna reported in a United States survey that 68% of residents had some outside or overseas experience to increase surgical volume.<sup>3</sup> Second, the majority of the tech-

nical aspects of cataract microsurgery involve one operating surgeon ("one person driving") and typically only one assistant surgeon. Third, the increased use of topical anesthesia for most cataract procedures makes it difficult to provide meaningful and timely feedback to the operating resident during the procedure in the awake patient. There is also selection bias towards more senior resident surgeons performing the topical cases for various reasons (e.g., patient movement, patient sensation during surgery). Fourth, errors in an early stage of the procedure (e.g., wound construction, capsulorrhexis) can lead to downstream complications or difficulty with other parts of the procedure. Fifth, intraocular microsurgery has a narrow tolerance for intraoperative error, and even small missteps in surgical judgment or technique may result in irreversible adverse surgical outcomes. Sixth, virtual intraocular surgery, though promising, is not advanced sufficiently at this time to replace the wet laboratory or live patient surgical experience. To address the various technical, ethical, and practical issues of live surgery and surgical teaching, the residency review committee in ophthalmology has mandated that a wet laboratory experience is required for all ophthalmology programs. We review the literature on the wet laboratory experience, glean best practices, and from our experience propose an implementation matrix for the ophthalmology wet laboratory (OWL) curriculum.

## Materials and Methods

At the University of Iowa, the department of ophthalmology has formed a task force on the competencies to manage the ACGME mandate. The core of our strategy and our local implementation matrix for the ACGME competencies are listed in [Table 1](#). We have applied these core strategies to the development of the Iowa OWL curriculum plan. The wet laboratory curriculum was devel-

Originally received: March 29, 2006.

Accepted: July 4, 2006.

Manuscript no. 2006-382.

<sup>1</sup> Department of Ophthalmology, University of Iowa Hospital and Clinics, Iowa City, Iowa.

<sup>2</sup> Departments of Neurology and Neurosurgery, University of Iowa Hospital and Clinics, Iowa City, Iowa.

<sup>3</sup> Veterans Affairs Medical Center, Iowa City, Iowa.

<sup>4</sup> Department of Electrical and Computer Engineering, University of Iowa, Iowa City, Iowa.

Supported in part by an unrestricted grant from Research to Prevent Blindness, Inc., New York, New York.

Correspondence to Andrew G. Lee, MD, Department of Ophthalmology, University of Iowa Hospitals and Clinics, 200 Hawkins Drive, Iowa City, IA 52242. E-mail: Andrew-lee@uiowa.edu.

Table 1. Core Strategy for Implementing the Accreditation Council for Graduate Medical Education Competencies

1. A predefined curriculum (explicit written learning objectives)
2. A pretest (i.e., a needs assessment to define the educational gap)
3. A posttest (i.e., an assessment of how effective the intervention was at closing the knowledge gap)
4. Feedback mechanisms
  - a. Formative
  - b. Summative
5. Documentation of performance (Schön reflection model)
6. Prerequisite knowledge reading list
7. Mandatory wet laboratory completion (Ericsson deliberate practice model)
8. Documentation of stepwise performance (Dreyfus model)
9. Means of documenting performance outcomes (e.g., portfolio)
  - a. Videotaped cases
  - b. Surgical log
  - c. Sentinel event markers (e.g., vitreous loss, anterior chamber lens insertion, endophthalmitis, return to operating room within 2 wks)
  - d. Quality indices (e.g., visual outcomes, surgical times)
  - e. Chart audit
  - f. Objective structured checklist

oped by 2 members of the task force, who supervise resident surgery at the Iowa City Veteran's Affairs Medical Center (EG, TAO), and underwent a face validation evaluation by the members of the task force, including supervising faculty surgeons for cataract at the University of Iowa Hospitals and Clinics (HAB, ATJ), the department chairman (KC), and a content expert for the ACGME competencies (AGL). A literature review (PubMed, English language, 1966–2006) was performed to define existing tools, including prior wet laboratory curricular materials for teaching and assessing surgical competency.<sup>4–63</sup> The content expert (AGL) reviewed the titles and reviewed selected articles of relevance to the development of a wet laboratory curriculum. A pretest and posttest were defined by the content experts (EG, TAO) to assess cognitive skills in the wet laboratory and was modified by the task force for implementation. An objective skills assessment tool and global evaluation form for the wet laboratory experience also were constructed by the content experts and externally validated by the task force.

## Results

The Iowa task force on the competencies reviewed the Iowa OWL curriculum and the available literature results. Table 1 lists our core strategy for implementing the ACGME mandate. The curriculum includes explicit written learning objectives and incorporates a pretest (i.e., a needs assessment to define the educational gap) and a posttest (an assessment of how effective the intervention was at closing the gap). We emphasize the importance of feedback mechanisms (formative and summative). We employ the Schön reflection model to improve learner understanding and motivation for learning.<sup>42</sup> The Schön model includes reflection on action (e.g., recognizing the need for further knowledge and learning), reflection in action (e.g., utilizing practice-based learning techniques, reviewing and synthesizing available evidence-based medicine), and knowledge in action (e.g., application of learning in the real-world patient context).<sup>42</sup> We include prerequisite reading material before entrance into the wet laboratory. As part of the wet laboratory experience, we also emphasize the Ericsson deliberate practice model.<sup>43,44</sup> In the Ericsson model, expertise is achieved by deliberate practice. Purposeful repetition, analysis of performance, and further refinement of technique are incorporated

into the Ericsson model of deliberate practice for wet laboratory techniques.<sup>43,44</sup> Documentation of stepwise performance using a criterion-referenced rating form (i.e., Dreyfus model) is described below. Specific means of documenting performance outcomes are vital for the assessment process (e.g., videotaped cases, surgical logs, sentinel event markers, quality indices, chart audit, objective structured checklist).

The task force defined cognitive and skill domains for the OWL. The American Board of Ophthalmology, in conjunction with the ACGME, has mandated the systematic assessment of surgical competence of ophthalmology residents at all residency programs. Cremers et al developed an objective assessment tool of skills in intraocular surgery (Objective Assessment of Skills in Intraocular Surgery [OASIS]). The authors believe that the OASIS has both face and content validity, and it is used to assess surgical events and surgical skill.<sup>9,10</sup> Cremers et al also reported a tool complementary to the OASIS to assess residents' surgical competence using a 1-page subjective evaluation form. This Global Rating Assessment of Skills in Intraocular Surgery was reported to have face and content validity and is expected to be useful for assessing "resident surgical knowledge and care, preparedness, and interpersonal skills."<sup>9,10</sup> Table 2 describes the Iowa OWL curriculum. Table 3 describes the Iowa OWL quiz for defining competency in selected cognitive domains for the wet laboratory. This quiz serves as the pretest and posttest for the cognitive portion of the OWL.

Most of the existing ophthalmic literature on the resident wet laboratory experience has focused on the actual devices and models (e.g., animal, cadaveric, simulated, synthetic) for surgical tech-

Table 2. First-Year Resident Iowa Ophthalmology Wet Laboratory Curriculum

### Objectives

During the 10-wk rotation at the Iowa City Veteran's Affairs Medical Center, the first-year resident will have 5 half-day sessions in the wet laboratory with staff supervision. Additional unsupervised individual practice time in the wet lab is required, and the resident should maintain in his or her resident portfolio a log of supervised and unsupervised wet laboratory attendance.

As a prerequisite to the wet laboratory experience, residents are required to read *Cataract Surgery for Greenhorns*\* and *Phacodynamics*† in the 2 wks before beginning the service so that optimal time may be spent in the wet laboratory and operating room.

The objectives of the wet lab are as follows:

1. To demonstrate fine motor and proprioception skills while operating under the microscope
2. To demonstrate proficiency in working in a small surgical field as both a surgeon and assistant using the microscope
3. To list the differences in phacoemulsification machines and the settings for each machine
4. To describe the pedal settings on a phacoemulsification machine and demonstrate the use of the pedal for the microscope
5. To demonstrate performance of 5 adequate corneal and scleral incisions for cataract or glaucoma surgeries using a cadaver or animal eye
6. To identify the steps of phacoemulsification
7. To demonstrate performance of the steps of phacoemulsification on pig or cadaver eyes
8. To list the various types of ophthalmic sutures
9. To demonstrate ability to pass corneal, scleral, and simulated conjunctival or skin sutures for closure

\*Oetting TA. Cataract surgery for greenhorns. Available at <http://webeye.ophth.uiowa.edu/eyeforum/cataract-oetting.htm>. Accessed March 27, 2006.

†Seibel BS. Phacodynamics: Mastering the Tools and Techniques of Phacoemulsification Surgery. 4th ed. Thorofare, NJ: SLACK Inc.; 2005.

Table 3. The University of Iowa Ophthalmology Wet Laboratory Quiz

1. Which of the following is one of the main differences between a peristaltic pump and a Venturi pump?
  - a. A peristaltic pump is driven by compressed gas.
  - b. Vacuum builds more rapidly with a Venturi pump.
  - c. The rise time of a peristaltic pump is independent of flow rate.
  - d. A Venturi pump is driven by a rotating head that rolls over the aspiration tubing.
2. Which is the correct order of steps for clear corneal phacoemulsification? The steps regarding viscoelastic insertion and removal have been disregarded.
  - a. Clear corneal incision, paracentesis, capsulorrhexis, phacoemulsification, hydrodissection, cortical removal, IOL insertion, corneal wound stabilization.
  - b. Clear corneal incision, paracentesis, hydrodissection, phacoemulsification, capsulorrhexis, cortical removal, IOL insertion, corneal wound stabilization.
  - c. Paracentesis, clear corneal incision, capsulorrhexis, hydrodissection, phacoemulsification, cortical removal, IOL insertion, corneal wound stabilization.
  - d. Paracentesis, capsulorrhexis, clear corneal incision, hydrodissection, phacoemulsification, cortical removal, IOL insertion, corneal wound stabilization.
3. What are the indications for extracapsular cataract or intracapsular cataract extractions in the age of modern-day phacoemulsification?
  - a. Extracapsular cataract extractions should be considered in patients with dense cataracts who are at risk for corneal decompensation.
  - b. Intracapsular cataract extractions should be considered for patients with posterior polar cataracts.
  - c. Extracapsular cataract extractions should be considered in patients with posterior subcapsular cataracts.
  - d. Intracapsular cataract extractions should be considered in patients with a history of phacolytic glaucoma.
4. What are functions of the pedal positions on the phacoemulsification foot pedal?
  - a. Position 1 aspirates only.
  - b. Position 2 aspirates and phacoemulsifies.
  - c. Position 3 irrigates, aspirates, and phacoemulsifies.
  - d. Position 4 irrigates, aspirates, phacoemulsifies, and refluxes.
5. What is the difference between hydrodissection and hydrodelineation?
  - a. Hydrodissection is performed before the capsulorrhexis, and hydrodelineation afterwards.
  - b. Hydrodissection cleaves between the capsule and cortex, and hydrodelineation between the cortex and nucleus.
  - c. Hydrodissection is performed for phacoemulsification, and hydrodelineation for extracapsular cataract extractions.
  - d. Hydrodissection is performed before initial groove formation, and hydrodelineation before segment removal.
6. What is the average axial eye length?
  - a. 20 mm.
  - b. 21 mm.
  - c. 22 mm.
  - d. 23 mm.
7. What are average keratometry readings?
  - a. 40 D.
  - b. 41 D.
  - c. 42 D.
  - d. 43 D.
8. What is the average scleral thickness?
  - a. 0.5 mm.
  - b. 1.0 mm.
  - c. 1.5 mm.
  - d. 2.0 mm.
9. Where is the sclera the thinnest?
  - a. The limbus.
  - b. Around the optic nerve.
  - c. Posterior to the rectus muscles.
  - d. At the exit site of the vortex veins.
10. What is considered an average range for corneal thickness?
  - a. 480–500  $\mu\text{m}$ .
  - b. 520–550  $\mu\text{m}$ .
  - c. 580–600  $\mu\text{m}$ .
  - d. 610–630  $\mu\text{m}$ .

D = diopters; IOL = intraocular lens.

Answers: 1, b; 2, c; 3, a; 4, c; 5, b; 6, d; 7, d; 8, b; 9, c; 10, b.

nique rather than teaching and assessing in a curriculum format.<sup>45–61</sup> Table 4 describes the Iowa OWL Structured Assessment of Skill and Technique scoring rubric. The Assessment is similar to other structured surgical assessment tools that have been pro-

posed in other surgical specialties for assessing surgical skills and knowledge.<sup>12,13,16–20</sup> The scoring rubric does not employ a norm-referenced scale (i.e., below average, average, above average, etc.) and instead uses a criterion-referenced scale that is behavior spe-

Table 4. University of Iowa Department of Ophthalmology Objective Wet Laboratory Structured Assessment of Skill and Technique (OWLSAT) Scoring Rubric

- A. The resident will be able to name the instruments used in cataract surgery. Ten instruments presented.
1. Able to name only 2 instruments.
  2. Able to name 4 instruments.
  3. Able to name 6 instruments.
  4. Able to name 8 instruments.
  5. Able to name all 10 instruments.
- B. The resident shall identify different sutures presented, determine dissolvability, and describe indications for usage. Four sutures presented.
1. Unable to identify any sutures presented.
  2. Identifies 1 suture presented.
  3. Identifies 2 sutures presented.
  4. Identifies 3 sutures presented.
  5. Identifies 4 sutures presented.
- C. The resident shall demonstrate proper paracentesis and corneal wound incisions.
1. Improper placement of incisions for handedness.
  2. Placement of incisions  $<30^\circ$  from one another.
  3. Proper creation of paracentesis with placement of corneal incision without a 3-step entry.
  4. Proper creation of paracentesis and corneal incision but incision too long, creating corneal striae, or too posterior of entry, leading to iris prolapse.
  5. Proper placement and length of corneal incisions.
- D. The resident shall demonstrate ability to perform scleral tunnel incision.
1. Inadvertent entry posterior to iris.
  2. Failure to create initial scleral groove.
  3. Entry into anterior chamber with posterior entrance resulting in iris prolapse.
  4. Creation of long scleral tunnel with decreased visibility through cornea.
  5. Scleral tunnel incision with adequate 3-step entrance and length.
- E. The resident shall demonstrate ability to perform continuous curvilinear capsulorhexis.
1. Inability to make initial tear in anterior capsule.
  2. Radial tear extending posteriorly.
  3. Creation of small capsulorhexis ( $<5$  mm).
  4. Creation of large capsulorhexis ( $>8$  mm) resulting in optic prolapse.
  5. Creation of adequately sized capsulorhexis with easy insertion of IOL and good fixation.
- F. The resident shall demonstrate ability to perform divide-and-conquer phacoemulsification technique.
1. Initiation of phacoemulsification before hydrodissection.
  2. Off-center placement of initial groove.
  3. Inability to crack nucleus with 2 instruments.
  4. Ability to crack into 4 quadrants but inability to engage and remove during segment removal.
  5. Adequate grooving and cracking with successful removal of 4 quadrants.
- G. The resident shall demonstrate a scleral trabeculectomy flap.
1. Inadvertent posterior chamber entry with encountered vitreous.
  2. Creation of thin flap resulting in tearing of the flap at the limbus.
  3. Wide flap incision resulting in hypotony.
  4. Irregular incision edges with resulting hypotony.
  5. Clean, sharp wound edges with adequate flap thickness and good IOP.
- H. The resident shall pass and tie 2 corneal sutures.
1. Inability to pass and tie 2 corneal sutures in 3 min.
  2. Passed suture pulled out more than once.
  3. Passed suture placed but too loose.
  4. Passed suture placed with adequate tension within 2 min.
  5. Passed sutures placed with adequate tension within 1 min.
- I. The resident shall pass and tie 2 scleral sutures.
1. Inability to pass and tie 2 scleral sutures in 3 min.

(continued)

Table 4. (Continued)

2. Passed suture pulled out more than once.
  3. Passed suture placed but too loose.
  4. Passed suture placed with adequate tension within 2 min.
  5. Passed sutures placed with adequate tension within 1 min.
- J. The resident shall place a running suture for conjunctival or skin closure.
1. Improper selection of suture/needle for tissue.
  2. Inability to tie initial square knot with instruments.
  3. Poor wound apposition or eversion.
  4. Difficulty using second instrument to fix tissue for suturing.
  5. Good apposition of wound edges with nice immediate reloading of needle as it is passed through tissue.
- Score**  
Recommendations for improvement:
1. Reading assignment.
  2. Unsupervised wet laboratory experience.
  3. Supervised wet laboratory experience.
  4. Repeat OWLSAT.

IOL = intraocular lens; IOP = intraocular pressure.

cific. Previous work has described the advantages of criterion-referenced over norm-referenced scales, and prior work emphasizes the Dreyfus model of expertise. In the Dreyfus model, learners are expected to move through stages of expertise (i.e., novice, beginner, advanced beginner, proficient-competent, and expert).<sup>36,37,41</sup> The use of the Dreyfus model for the scoring rubric allows for formative feedback to allow the resident the opportunity for improvement and includes specific behavioral anchors in the rubric for reinforcing change over time.<sup>36,37,41</sup>

## Discussion

The teaching of ophthalmic surgery to residents is a difficult and challenging task with unique ethical, technical, and practical problems. We believe that the residency review committee requirement for a wet laboratory experience can be an important method for teaching and assessing surgical competence. Emerging work by other authors in this area continues to expand our application of these methods.<sup>62,63</sup> We recognize the limitations of our work, including the (1) preliminary nature of the curriculum; (2) small sample size, involving only one institution; and (3) lack of documented improvement in surgical outcome. There are many questions that remain, including:

1. What is the faculty and department cost in time and money for implementing the OWL curriculum?
2. How do the learners feel about the OWL experience?
3. Does the OWL process improve actual surgical performance and surgical outcomes?
4. Does performance in the OWL predict future surgical outcomes or performance with other assessment tools such as the OASIS and Global Rating Assessment of Skills in Intraocular Surgery?

These questions will require further study in the future, but despite the limitations of our work, we believe that the OWL curriculum will be of value in teaching and assessing surgical competency.

## References

1. Lee AG, Carter KD. Managing the new mandate in resident education. A blueprint for translating a national mandate into local compliance. *Ophthalmology* 2004;111:1807–12.
2. Lee AG. The new competencies and their impact on resident training in ophthalmology. *Surv Ophthalmol* 2003;48:651–62.
3. Rowden A, Krishna R. Resident cataract surgical training in United States residency programs. *J Cataract Refract Surg* 2002;28:2202–5.
4. Nielsen PE, Foglia LM, Mandel LS, Chow GE. Objective structured assessment of technical skills for episiotomy repair. *Am J Obstet Gynecol* 2003;189:1257–60.
5. Goff BA, Lentz GM, Lee D, et al. Development of a bench station objective structured assessment of technical skills. *Obstet Gynecol* 2001;98:412–6.
6. Goff BA, Nielsen PE, Lentz GM, et al. Surgical skills assessment: a blinded examination of obstetrics and gynecology residents. *Am J Obstet Gynecol* 2002;186:613–7.
7. Reznick RK. Teaching and testing technical skills. *Am J Surg* 1993;165:358–61.
8. Dunnington GL, Wright K, Hoffman K. A pilot experience with competency-based clinical skills assessment in a surgical clerkship. *Am J Surg* 1994;167:604–6.
9. Cremers SL, Lora AN, Ferrufino-Ponce ZK. Global Rating Assessment of Skills in Intraocular Surgery (GRASIS). *Ophthalmology* 2005;112:1655–60.
10. Cremers SL, Ciolino JB, Ferrufino-Ponce ZK, Henderson BA. Objective Assessment of Skills in Intraocular Surgery (OASIS). *Ophthalmology* 2005;112:1236–41.
11. Cuschieri A, Francis N, Crosby J, Hanna GB. What do master surgeons think of surgical competence and revalidation? *Am J Surg* 2001;182:110–6.
12. Reznick R, Regehr G, MacRae H, et al. Testing technical skill via an innovative “bench station” examination. *Am J Surg* 1997;173:226–30.
13. Scott DJ, Valentine RJ, Bergen PC, et al. Evaluating surgical competency with the American Board of Surgery In-Training Examination, skill testing, and intraoperative assessment. *Surgery* 2000;128:613–22.
14. Bilimoria K, Abbott D, Wayne J. How to design a pilot system for tracking adverse and near-miss events in surgical patients. Available at: <http://www.facs.org/education/rap/bilimoria.html>. Accessed September 22, 2005.
15. McCloy R, Stone R. Science, medicine, and the future: virtual reality in surgery. *BMJ* 2001;323:912–5.
16. Taffinder N, Sutton C, Fishwick RJ, et al. Validation of virtual reality to teach and assess psychomotor skills in laparoscopic surgery: results from randomised controlled studies using the MIST VR laparoscopic simulator. *Stud Health Technol Inform* 1998;50:124–30.
17. Darzi A, Datta V, Mackay S. The challenge of objective assessment of surgical skill. *Am J Surg* 2001;181:484–6.
18. Moorthy K, Munz Y, Dosis A, et al. Motion analysis in the training and assessment of minimally invasive surgery. *Minim Invasive Ther Allied Technol* 2003;12:137–42.
19. Moorthy K, Munz Y, Sarker SK, Darzi A. Objective assessment of technical skills in surgery. *BMJ* 2003;327:1032–7.
20. Kopta JA. An approach to the evaluation of operative skills. *Surgery* 1971;70:297–303.
21. Bridges M, Diamond DL. The financial impact of teaching surgical residents in the operating room. *Am J Surg* 1999;177:28–32.
22. Skidmore FD. Junior surgeons are becoming deskilled as result of Calman proposals [letter]. *BMJ* 1997;314:1281.
23. Darzi A, Smith S, Taffinder N. Assessing operative skill needs to become more objective. *BMJ* 1999;318:887–8.
24. Martin JA, Regehr G, Reznick R, et al. Objective structured assessment of technical skill (OSATS) for surgical residents. *Br J Surg* 1997;84:273–8.
25. Bridgewater B, Grayson AD, Jackson M, et al. Surgeon specific mortality in adult cardiac surgery: comparison between crude and risk stratified data. *BMJ* 2003;327:13–7.
26. Regehr G, MacRae H, Reznick RK, Szalay D. Comparing the psychometric properties of checklists and global rating scales for assessing performance on an OSCE-format examination. *Acad Med* 1998;73:993–7.
27. Datta V, Chang A, Mackay S, Darzi A. The relationship between motion analysis and surgical technical assessments. *Am J Surg* 2002;184:70–3.
28. Datta V, Mackay S, Mandalia M, Darzi A. The use of electromagnetic motion tracking analysis to objectively measure open surgical skill in the laboratory-based model. *J Am Coll Surg* 2001;193:479–85.
29. Smith SG, Torkington J, Brown TJ, et al. Motion analysis. *Surg Endosc* 2002;16:640–5.
30. Francis NK, Hanna GB, Cuschieri A. The performance of master surgeons on the Advanced Dundee Endoscopic Psychomotor Tester: contrast validity study. *Arch Surg* 2002;137:841–4.
31. Emam TA, Hanna GB, Kimber C, Cuschieri A. Differences between experts and trainees in the motion pattern of the dominant upper limb during intracorporeal endoscopic knotting. *Dig Surg* 2000;17:120–3.
32. Satava RM, Cuschieri A, Hamdorf J. Metrics for objective assessment. *Surg Endosc* 2003;17:220–6.
33. Szalay D, MacRae H, Regehr G, Reznick R. Using operative outcome to assess technical skill. *Am J Surg* 2000;180:234–7.
34. Datta V, Mandalia M, Mackay S, et al. Relationship between skill and outcome in the laboratory-based model. *Surgery* 2002;131:318–23.
35. Hanna GB, Frank TG, Cuschieri A. Objective assessment of endoscopic knot quality. *Am J Surg* 1997;174:410–3.
36. Benner P. Using the Dreyfus model of skill acquisition to describe and interpret skill acquisition and clinical judgment in nursing practice and education. *Bull Sci Technol Soc* 2004;24:188–99.
37. Batalden P, Leach D, Swing S, et al. General competencies and accreditation in graduate medical education. *Health Aff (Millwood)* 2002;21:103–11.
38. Evans AW. Assessing competence in surgical dentistry. *Br Dent J* 2001;190:343–6.
39. Williams RG. The 10 commandments of performance appraisal provide a foundation for the surgical training process. Available at: <http://www.facs.org/education/rap/williams.html>. Accessed September 22, 2005.
40. Kohls-Gatzoulis JA, Regehr G, Hutchinson C. Teaching cognitive skills improves learning in surgical skills courses: a blinded, prospective, randomized study. *Can J Surg* 2004;47:277–83.
41. Dreyfus HL. Intuitive, deliberative, and calculative models of expert performance. In: Zsombok CE, Klein G, eds. *Naturalistic Decision Making*. Mahwah, NJ: L. Erlbaum Associates; 1997:17–28.44. The Encyclopedia of Informal Education.
42. Smith MK. Donald Schön: learning, reflection and change. 2001. Available at <http://www.infed.org/thinkers/et-schon.htm>. Accessed March 29, 2006.
43. Ericsson KA, Krampe RT, Tesch-Roemer C. The role of deliberate practice in the acquisition of expert performance. *Psychol Rev* 1993;100:363–406.
44. Ericsson KA. Expertise in interpreting: an expert-performance

- perspective. Interpreting [serial online] 2000;5:187–220. Available at: [http://www.benjamins.com/cgi-bin/t\\_articles.cgi?bookid=INTP\\_5\\_2&artid=278022316](http://www.benjamins.com/cgi-bin/t_articles.cgi?bookid=INTP_5_2&artid=278022316). Accessed March 29, 2006.
45. Otto CS. Device for simulating anterior segment surgery. *J Cataract Refract Surg* 2005;31:1287–9.
  46. Lee GA, Chiang MY, Shah P. Pig eye trabeculectomy—a wet-lab teaching model. *Eye* 2006;20:32–7.
  47. Qayumi AK, Cheifetz RE, Forward AD, et al. Teaching and evaluation of basic surgical techniques: the University of British Columbia experience. *J Invest Surg* 1999;12:341–50.
  48. Lossing AG, Hatswell EM, Gilas T, et al. A technical-skills course for 1st-year residents in general surgery: a descriptive study. *Can J Surg* 1992;35:536–40.
  49. Borirak-Chanyavat S, Lindquist TD, Kaplan HJ. A cadaveric model for practicing anterior and posterior segment surgeries. *Ophthalmology* 1995;102:1932–5.
  50. Lenart TD, McCannel CA, Baratz KH, Robertson DM. A contact lens as an artificial cornea for improved visualization during practice surgery on cadaver eyes. *Arch Ophthalmol* 2003;121:16–9.
  51. Castellano D, Spraul J, Whitaker TE. A simple, cost-effective method for practicing phacoemulsification in the cadaveric eye. *Ophthalmic Surg Lasers* 1998;29:253–6.
  52. Oram O, Gross RL, Severin TD, et al. A human cadaver eye model for anterior and posterior segment laser applications. *Ophthalmic Surg* 1994;25:449–51.
  53. Rootman DS, Marcovich A. Utilizing eye bank eyes and keratoplasty techniques to teach phacoemulsification. *Ophthalmic Surg Lasers* 1997;28:957–60.
  54. Coroneo MT. The bovine eye as a model for the novice cataract surgeon. *Ophthalmic Surg* 1990;21:772–7.
  55. Mekada A, Nakajima J, Nakamura J, et al. Cataract surgery training using pig eyes filled with chestnuts of various hardness. *J Cataract Refract Surg* 1999;25:622–5.
  56. Hashimoto C, Kurosaka D, Uetsuki Y. Teaching continuous curvilinear capsulorrhexis using a postmortem pig eye with simulated cataract. *J Cataract Refract Surg* 2001;27:814–6.
  57. Sugiura T, Kurosaka D, Uezuki Y, et al. Creating cataract in pig eye. *J Cataract Refract Surg* 1999;25:615–21.
  58. Dada VK, Sindhu N. Cataract in enucleated goat eyes: training model for phacoemulsification. *J Cataract Refract Surg* 2000;26:1114–6.
  59. Sudan R, Titiyal JS, Rai H, Chandra P. Formalin-induced cataract in goat eyes as a surgical training model for phacoemulsification. *J Cataract Refract Surg* 2002;28:1904–6.
  60. Tolentino FI, Liu HS. A laboratory animal model for phacoemulsification practice. *Am J Ophthalmol* 1975;80:545–6.
  61. Yip CC, Heng WJ, Au Eong KG, Yong VS. A novel approach for the fixation of enucleated eyes during microsurgical procedures using common household plumbing accessories. *Ophthalmic Surg Lasers* 2001;32:166–7.
  62. Fisher JB, Binenbaum G, Tapino P, Volpe NJ. Development and face and content validity of an eye surgical skills assessment test for ophthalmology residents. *Ophthalmology*. In press.
  63. Binenbaum G, Volpe NJ. Ophthalmology resident surgical competency. A national survey. *Ophthalmology* 2006;113:1237–44.