The Resident Surgeon Phacoemulsification Learning Curve

J. Bradley Randleman, MD; Jeremy D. Wolfe, MD; Maria Woodward, MD; Michael J. Lynn, MS; D. Hunter Cherwek, MD; Sunil K. Srivastava, MD

Objectives: To analyze outcomes of resident-performed phacoemulsifications and to assess the resident phacoemulsification learning curve.

Methods: Retrospective chart review of resident-performed phacoemulsification cases at the Atlanta Veterans Affairs Medical Center, Decatur, Georgia, from July 1, 1999, through June 30, 2002. Outcomes measured included postoperative uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), intraoperative complications, and adjusted phacoemulsification times (total phacoemulsification time multiplied by phacoemulsification power used).

Results: We analyzed 680 cases. Postoperative mean UCVA was 20/39, and mean BSCVA was 20/25 (20/20 in 44.0% of cases and 20/40 in 97.8%). There were no differences in visual acuity outcomes over the course of residency training. Intraoperative complications occurred in 34 cases (5.0%), with a significant reduction in vitreous loss rates after the first 80 resident cases (5.1% vs 1.9%; P = .03). Mean adjusted phacoemulsification time was 0.68 minutes, with a significant reduction in adjusted phacoemulsification time after the first 80 cases (0.87 vs 0.52 minutes; P < .001).

Conclusions: Quality visual outcomes after phacoemulsification can be attained throughout residency training; however, surgical competency, when measured by complication rates and phacoemulsification efficiency, continues to improve significantly with increasing surgical experience well beyond the first 80 resident phacoemulsification cases.

Arch Ophthalmol. 2007;125(9):1215-1219

Author Affiliations: Departments of Ophthalmology (Drs Randleman, Wolfe, Woodward, Cherwek, and Srivastava) and Biostatistics, Rollins School of Public Health (Mr Lynn), Emory University, Atlanta, Georgia.
Cases were excluded from analysis if there was insufficient information recorded or if the patient had preoperatively diagnosed ocular comorbidities that limited postoperative visual acuity. The statistical methods used for data analysis and comparisons included the unpaired, 2-tailed t test and χ² analysis.

A total of 762 cases were identified; of these, 680 (89.2%) were included in the final analysis. Eighty-two cases (10.8%) were excluded, including 26 (32%) because of insufficient data and 56 (68%) because of ocular comorbidities limiting the final BSCVA. Most of the excluded cases had preoperative retinal abnormalities (Table). Mean (SD) patient age at the time of surgery was 68.9 (10.3) years (range, 40-100 years), and 665 cases (97.8%) were male. Mean preoperative BSCVA was 20/64 (range, hand motions to 20/25), and mean (SD) MRSE was −0.7 (2.7) diopters (D) (range, −25 to +9 D).

There was an even case distribution among residents with regard to patient age, sex, and operative eye. Fifteen residents performed phacoemulsification during the study period under the guidance of 17 attending surgeons, with a relatively even case distribution between residents (mean [SD] number of cases, 45; range, 18-82).

Mean postoperative UCVA was 20/39; UCVA was 20/20 or better in 16.4% of cases and 20/40 or better in 77.0%. Mean BSCVA improved from 20/65 preoperatively to 20/25 postoperatively (P < .001); BSCVA was 20/20 or better in 44.0% of cases, and was 20/40 or better in 97.8%. Mean MRSE improved from −0.7 D to −0.4 D (P = .005). On average, eyes gained 4 lines of BSCVA postoperatively (range, 14 lines gained to 6 lines lost). There was no significant change in cylinder postoperatively (0.86 vs 0.85 D, P = .8).

There were no significant changes in UCVA or BSCVA outcomes (Figure 1) during residency training. Overall, intraoperative complications occurred in 34 cases (5.0%), with some cases experiencing more than 1 complication. These included 33 cases (4.9%) with posterior capsule tear, 23 (3.4%) with vitreous loss, 3 (0.4%) with retained lens fragments, and 3 (0.4%) with wound injury, including wound burns or small Descemet detachments. There were too few cases of retained lens fragments or wound injury to make meaningful comparisons; however, when resident cases 1 through 80 (315 cases) were compared with cases 81 through 207 (365 cases), there were fewer cases with posterior capsule tears (6.3% vs 3.5%; P = .2) and significantly fewer cases with vitreous loss (5.1% vs 1.9%; P = .03) later in training. Posterior capsule tear and vitreous loss rates continued to decrease throughout residency training (Figure 2). There were no significant differences in UCVA (20/48 vs 20/39; P = .15) or BSCVA (20/28 vs 20/25; P = .13) between cases with and without vitreous loss.

Mean (SD) adjusted phacoemulsification time was 0.68 (0.5) minutes. When resident cases 1 through 80 were compared with cases 81 through 207, there was a significant reduction in adjusted phacoemulsification time (0.87 vs 0.52 minutes; P < .001) later in training. Adjusted phacoemulsification times continued to decrease throughout residency training (Figure 3).

### METHODS

The surgical logs from the Department of Ophthalmology at Emory University and from the Atlanta Veterans Affairs Medical Center (Atlanta VA) in Decatur, Georgia, were accessed to identify all phacoemulsification cases performed by residents during a 3-year academic period from July 1, 1999, through June 30, 2002. The charts for all identified cases performed at the Atlanta VA during the study interval were reviewed. The Emory University and the Atlanta VA institutional review boards granted approval for this study.

During the study period, all phacoemulsification at the Atlanta VA was performed by resident surgeons after approval by attending ophthalmologists. There were no differences in criteria for case selection throughout the academic year; thus, there was no significant variability in case difficulty that might affect outcomes.

Phacoemulsification was performed by the residents with a relatively uniform technique for all cases. While patients were under topical or local anesthesia, residents created scleral tunnel incisions for a few of the early cases and then began to use oblique clear cornea incisions. A continuous curvilinear capsulorhexis was performed. The lens was then phacoemulsified, usually with a “divide-and-conquer” technique. When possible, foldable acrylic or silicone intraocular lenses were inserted into the capsular bag. Alternatively, foldable or polymethylmethacrylate lenses were placed within the ciliary sulcus or, when necessary, polymethylmethacrylate anterior chamber lenses were placed in the anterior chamber angle.

Preoperative data collected included patient age, sex, operative eye, best spectacle-corrected visual acuity (BSCVA), manifest refraction spherical equivalent (MRSE), and ocular comorbidities. Operative data obtained for each case (when available) included resident surgeon, attending surgeon, date of operation, adjusted phacoemulsification time (total phacoemulsification time multiplied by phacoemulsification power used), intraoperative complications, and resident case number. The resident case number was established by first sorting all phacoemulsification cases performed at all facilities chronologically for each resident and then assigning each case its sequential number. Thus, the case numbers used for analysis reflect the actual experience of the individual resident performing the surgery rather than the exact sequential order of cases performed at the Atlanta VA during the study period. Intraoperative complications recorded included posterior capsule tear, vitreous loss, retained lens fragments, and Descemet detachments or wound burns. Postoperative information collected included uncorrected visual acuity (UCVA), BSCVA, and MRSE at the 1-month postoperative visit.

### Exclusion Criteria

<table>
<thead>
<tr>
<th>Exclusion Criteria</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient data</td>
<td>26 (32)</td>
</tr>
<tr>
<td>Ocular comorbidities</td>
<td>56 (68)</td>
</tr>
<tr>
<td>Advanced glaucoma</td>
<td>5 (6)</td>
</tr>
<tr>
<td>Optic neuropathy</td>
<td>4 (5)</td>
</tr>
<tr>
<td>Amblyopia</td>
<td>2 (4)</td>
</tr>
<tr>
<td>Retinal complications</td>
<td>44 (54)</td>
</tr>
<tr>
<td>Diabetic complications</td>
<td>28 (34)</td>
</tr>
<tr>
<td>AMD</td>
<td>9 (11)</td>
</tr>
<tr>
<td>Retinal detachment</td>
<td>4 (5)</td>
</tr>
<tr>
<td>BRVO</td>
<td>2 (2)</td>
</tr>
<tr>
<td>Macular hole</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

Abbreviations: AMD, age-related macular degeneration; BRVO, branch retinal vein occlusion.
Phacoemulsification remains one of the most important skills to master during ophthalmology residency training. Although each surgeon will likely develop these skills at an individualized pace, and although some residents may face great challenges in acquiring fundamental surgical skills,22 ophthalmology residency training programs should have specific training guidelines and provide a realistic number of minimum surgical cases to help residents develop competency in performing phacoemulsification. Based on our study results, good visual outcomes can be attained early during residency training; however, surgical competency, when measured by complication rates and phacoemulsification efficiency, continues to improve with increasing surgical experience and does not plateau during residency training.

### VISUAL ACUITY OUTCOMES

Overall, most eyes achieved 20/40 or better UCVA and BSCVA after resident phacoemulsification. These results compare favorably with those of previous reports.* We found consistent visual acuity outcomes throughout residency training, with no significant trends over time. This is encouraging when one considers the substantial stress encountered by resident physicians and attending staff, especially during a resident's early cases.25-27

### COMPLICATIONS

The overall complication rate in this series compared favorably with those of previous reports.6,9,10,14,21,23,28 There were no cases of endophthalmitis in our study, and we

---

*References 3, 5, 6, 10, 11, 13, 14, 17, 19, 21, 23, 24.
found decreasing rates of posterior capsule tear and vitreous loss throughout residency training. The overall rate of vitreous loss was equivalent to that reported by Martin and Burton\(^9\) during the first 300 cases performed by an experienced surgeon learning phacoemulsification, a rate that dropped precipitously over the course of the first 3000 cases. Our data suggest that the learning curve, as it pertains to posterior capsule complications, extends beyond the first 200 resident cases. However, the vitreous loss rate after the first 80 cases (1.9%) seems quite acceptable; after 160 cases, this rate dropped even further, approaching that of experienced surgeons. Fortunately, vitreous loss did not significantly affect final visual acuity outcomes in our series.

**IMPROVED SURGICAL EFFICIENCY DURING RESIDENCY TRAINING**

We used adjusted phacoemulsification time as a marker for surgical efficiency during residency training. This seemed appropriate because the case selection and nucleus density remained constant throughout the resident's surgical experience; thus, changes in this variable could be attributed to improved surgical technique. We found significant differences between early and late resident cases, and adjusted phacoemulsification times continued to decrease throughout the study; thus, improvements in surgical efficiency appear to continue beyond the resident’s first 200 cases without reaching a plateau.

**EFFECT OF THE RESIDENT PHACOEMULSIFICATION LEARNING CURVE**

Residency training is clearly a balancing act, with residency programs using their available resources to provide residents with a comprehensive but balanced clinical and surgical experience to optimally prepare them for autonomous practice. Although the length of ophthalmology residency—almost exclusively 3 years of training following an internship year—has remained constant, significant advances in medical and surgical therapies in all areas of ophthalmology require the time and attention of residents during their training. Therefore, it is critical to strike the appropriate balance between teaching phacoemulsification and teaching other clinical and surgical skills. With this in mind, how can residency programs best partition their time?

The Residency Review Committee of the Accreditation Council for Graduate Medical Education\(^30\) has recently increased the minimum number of cataract procedures performed by the resident as primary surgeon from 45 to 86; based on our data, this increased minimum seems well justified. In fact, our results indicate that resident skills continue to improve significantly beyond this minimum number, and many programs should try to find ways to maximize their residents’ phacoemulsification volume.

**FUTURE DIRECTIONS**

Many new, evolving models assess and enhance resident surgical competency and may, ideally, improve the quality of the resident training experience.\(^{31-38}\) These models include skills-training exercises,\(^39\) resident surgical evaluation models,\(^{36,37,39}\) scoring systems for resident case selection,\(^{38,40}\) potential paradigm shifts in conceptual training models,\(^34\) and the promise of virtual simulator training.\(^32\) All of these approaches may improve the efficiency of resident surgical training and may shorten the learning curve. Nevertheless, there will likely be no substitute for actual operative experience, and ophthalmology residency programs should ensure that their graduates have access to the appropriate number of supervised surgical cases so that they may develop the skills necessary to perform phacoemulsification upon graduation.

Submitted for Publication: March 30, 2007; final revision received May 11, 2007; accepted May 17, 2007.

Correspondence: J. Bradley Randleman, MD, Department of Ophthalmology, Emory University, 1365 Clifton Rd NE, Ste 4500, Atlanta, GA 30322 (Jrandle@emory.edu).

Financial Disclosure: None reported.

Funding/Support: Supported in part by Research to Prevent Blindness, Inc, and core grant P30 EYO6360 from the National Institutes of Health.

**REFERENCES**

Until within about the past ten years, even the man who obtained an ophthalmic internship in this country was largely self taught. He was seldom taught anything by the staff of the hospital or required to learn much. The internship, however, gave him an excellent opportunity to teach himself. I am inclined to believe that the self-taught ophthalmologist is the best taught provided his teacher has high intellectual qualifications and adequate clinical and laboratory facilities. As anticipated by its founders, the American Board of Ophthalmology has improved the teaching of ophthalmology. . . .