

Resident surgeon efficiency in femtosecond laser-assisted cataract surgery

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Purpose: Comparison of resident surgeon performance efficiencies in femtosecond laser-assisted cataract surgery (FLACS) versus conventional phacoemulsification.

Patients and methods: A retrospective cohort study was conducted on consecutive patients undergoing phacoemulsification cataract surgery performed by senior ophthalmology residents under the supervision of 1 attending physician during a 9-month period in a large Veterans Affairs medical center. Medical records were reviewed for demographic information, preoperative nucleus grade, femtosecond laser pretreatment, operative procedure times, total operating room times, and surgical complications. Review of digital video records provided quantitative interval measurements of core steps of the procedures, including completion of incisions, anterior capsulotomy, nucleus removal, cortical removal, and intraocular lens implantation.

Results: Total room time, operation time, and corneal incision completion time were found to be significantly longer in the femtosecond laser group versus the traditional phacoemulsification group (each $P < 0.05$). Mean duration for manual completion of anterior capsulotomy was shorter in the laser group ($P < 0.001$). There were no statistically significant differences in the individual steps of nucleus removal, cortical removal, or intraocular lens placement. Surgical complication rates were not significantly different between the groups.

Conclusion: In early cases, resident completion of femtosecond cataract surgery is generally less efficient when trainees have more experience with traditional phacoemulsification. FLACS was found to have a significant advantage in completion of capsulotomy, but subsequent surgical steps were not shorter or longer. Resident learning curve for the FLACS technology may partially explain the disparities of performance. Educators should be cognizant of a potential for lower procedural efficiency when introducing FLACS into resident training.

Keywords: phacoemulsification, cataract extraction, curriculum, residency, learning curve

Introduction

Postgraduate ophthalmology residency curricula should include meaningful and evidence-based technological advancements to achieve necessary competencies for future clinical practice. Image-guided femtosecond laser-assisted cataract surgery (FLACS)¹⁻³ is an innovative technology that has been introduced into multiple teaching programs within the past several years, even though its routine use is not yet widespread among practicing ophthalmologists. A recent study indicated that ~21% of US residency programs actively train ophthalmology residents in performing FLACS, with numerous other programs planning to add FLACS into teaching curricula within 1–5 years.⁴ Early reported evidence has suggested good safety and outcomes when FLACS is performed by residents,^{5,6} but some controversy exists regarding higher costs and possible lower efficiency associated with this technology. Experienced cataract surgeons have been shown to have increased overall operating room (OR)

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times during the first 6 months while beginning to perform FLACS,⁷ but similar patterns by resident surgeons have not been reported.

The purpose of this study is to characterize FLACS efficiency when performed in a residency setting by senior-level trainees. Using a retrospective cohort study design at a single institution, we report time comparisons for completion of total procedures and for performance of key procedure steps in cases of femtosecond laser-assisted surgery versus conventional phacoemulsification.

Patients and methods

Approval of the proposed protocol by the Hines/Federal Healthcare Center Institutional Review Board (Hines, IL, USA) was obtained prior to initiation, and a waiver of requirement of patient informed consent for medical record review was also approved. The study subsequently conformed to all applicable institutional review board (IRB) oversight and followed the tenets of the Declaration of Helsinki, including protection of patient-sensitive data. Surgical scheduling records were used to identify cases of cataract surgery completed by senior (postgraduate year four [PGY4]) ophthalmology residents functioning as primary surgeons in a 9-month period from September 01, 2014, to May 31, 2015. By protocol, all the laser and traditional phacoemulsification procedures included in this study were performed under the supervision of 1 attending faculty who was an experienced femtosecond laser user. A total of 205 cases performed by 4 senior resident surgeons were determined eligible for data analysis, including 159 cases of conventional manual phacoemulsification and 46 cases of FLACS. The conventional phacoemulsification cohort had a mean age of 70.6 years (range: 43–89 years), with 148 men and 11 women. The mean age of the FLACS group was 73.9 years (range: 52–89 years), with 41 men and 5 women. For each case, the patient electronic medical records and the digital operating microscope video records were analyzed for data collection. De-identified patient data were recorded and stored on a secure local network server to maintain privacy and information security. The following information was recorded from each patient chart: age, gender, preoperative nucleus grade,⁸ resident surgeon, total OR time interval, total operating time interval, contraindications to FLACS,⁹ and intraoperative complications. Total OR time was defined as the minutes between patient entry and departure of the OR. For the purpose of this study, total operating time was defined as the start-to-finish interval for the manual procedure conducted under the operating microscope, not including the

time used for laser pretreatment when performed. Total room interval and total operating interval were obtained from routine nursing documentation that recorded specific room “in” time, procedure start time, procedure finish time, and room “out” time. Operative complications were defined as including one or more of the following unplanned occurrences: 1) posterior capsular tear with vitreous prolapse, 2) zonular dehiscence with vitreous prolapse, and/or 3) posteriorly dislocated nucleus or lens fragments. In the absence of any of the abovementioned 3 occurrences, an anterior capsular tear was not defined by the protocol as a major complication. However, isolated inadvertent anterior capsule tears were recorded upon review of the detailed operative reports and are reported later.

Data from digital video recordings were also collected. During each case, the operating microscope video had been routinely recorded and archived using an integrative device system (SwitchPoint Infinity 3; Stryker®, Kalamazoo, MI, USA). The microscope video files were analyzed using an editing software (VideoPad Video Editor™; NCH Software, Greenwood Village, CO, USA), and digital replay allowed for determination of recorded time intervals to a significant degree of ± 0.008 minutes. Specific performance times were collected from the video recording in each case for the following 5 key steps of the procedure: completion of incisions, completion of anterior capsulotomy, nucleus removal, cortical removal, and intraocular lens (IOL) implantation. Corneal incision completion time was defined as the total interval starting with application of a globe fixation ring to perform a single side port paracentesis and concluding with the finished patent primary incision, with inclusion of the in-between steps of intracameral lidocaine injection and viscoelastic injection after incising a single paracentesis. In cases of FLACS, completion of corneal incisions was defined as the time used to fully open 1 primary laser incision and 1 secondary laser incision using either a blunt Sinsky hook or an Eippert spatula and also including the time taken for lidocaine and viscoelastic injection after initially opening the side port incision. Completion of capsulotomy in the FLACS group was defined as the total time taken to harvest the round anterior capsule leaflet regardless of the presence or absence of capsular attachments. Nucleus removal time was defined as the total duration to disassemble and remove all nucleus material, including use of the ultrasound handpiece and use of manual nucleus dividing instrumentation when applicable. Cortical removal time was defined as the total interval to remove lens cortex from the capsular bag, measured by visible entry and removal of an automated irrigation/aspiration

handpiece. IOL insertion time was defined as the interval starting with introduction of the lens cartridge at the incision and concluding upon completion of IOL positioning but prior to viscoelastic removal.

Protocol exclusion criteria for data analysis were as follows: 1) attending faculty functioning as primary surgeon, 2) general anesthesia, 3) combined operations involving non-cataract components such as conjunctiva, cornea, glaucoma, or retina procedures, and 4) missing data required by the protocol including incomplete or absent video recording for each specific step.

Eyes with contraindications⁹ to femtosecond laser treatment had been assigned in the course of routine patient care to undergo conventional phacoemulsification, but these cases were not excluded from the cohort study unless one of the earlier exclusion criteria was met. Common examples include eyes with preexisting paracentral cornea opacities or eyes with inadequate pupil dilation at <5 mm. Patients on alpha adrenergic antagonist agents such as tamsulosin were considered eligible for FLACS if the dilated pupil was >5 mm. In our practice, the following less frequent conditions were also routinely deselected from laser pretreatment: pterygium, advanced glaucoma, previous filtration surgery, head tremor, or inability of patient to position flat for laser interface docking.

Eligible cases were selected for FLACS based on multiple safety and logistics concerns including absence of contraindications, patient willingness to undergo the procedure, scheduling, and laser access. Third-party reimbursement or out-of-pocket patient expenses were not factors affecting the decision for FLACS in the health care setting of the study.

All phacoemulsification procedures were performed with 2.0 mm temporal clear cornea incision technique under topical/intracameral anesthesia using a phacoemulsification microsurgical system (Stellaris[®] MICS[™]; Bausch+Lomb, Bridgewater, NJ, USA). IOLs included one of the following: monofocal lens (Akreos[®] AO; Bausch+Lomb), toric lens (AcrySof[®] IQ Toric lens; Alcon, Fort Worth, TX, USA), or multifocal lens (AcrySof IQ ReSTOR[®]; Alcon). When AcrySof lenses were implanted, the actual time used to enlarge the 2.0 mm incision to 2.4 mm prior to lens injection (typically 30–60 seconds) was not included in the recorded surgical step times.

Femtosecond laser pretreatment was performed using a Food and Drug Administration (FDA)-approved cataract refractive laser system (LenSx[®]; Alcon) located in the same OR as the remaining surgical procedure. In cases involving FLACS, laser pretreatment was included in the total room

times but not in the total microscope operational times. Similarly, time used for performance of laser treatment was not included in any of the individual surgical step time measurements.

Each femtosecond laser user completed a manufacturer-required 3-phase training program during 2013 and 2014. All users were current with product development updates involving software or hardware. Prior to the study period, an introductory educational program was conducted for OR nurses and technicians assigned to ophthalmology. OR personnel did not undergo formal manufacturer–user training, and non-physicians did not assist with the operation of the laser.

Analyses of results were performed using a statistical software platform (SPSS Statistics[®]; IBM, Armonk, NY, USA). The Fisher's exact test was used to perform univariate comparisons of the complication rates and gender demographics. Due to variability of patient age and individual resident surgeon performance, statistical significances (*P*) for comparison of mean time intervals were determined using a multivariable linear mixed-effects model controlling for age and allowing random intercepts for each resident. Statistical significance level was set at *P*=0.05.

Results

A total of 218 cases for the defined study period were initially identified and records reviewed. Thirteen cases were excluded due to general anesthesia (3 cases) and combined procedures (10 cases). A total of 205 cases performed by 4 senior resident surgeons under the supervision of a single attending surgeon, designated A through D, were determined eligible for data analysis, including 159 cases of conventional manual phacoemulsification and 46 cases of FLACS. Resident surgeon A performed 51 total cases including 11 FLACS. Resident B completed 41 cases with 14 FLACS. Resident C completed 71 cases with 12 FLACS. Resident D completed 42 cases with 9 FLACS. Prior to starting FLACS, Resident A had completed 34 conventional cases. Similarly, Residents B, C, and D had, respectively, completed 48, 29, and 44 conventional cases before FLACS.

Analysis of the demographic data of the conventional phacoemulsification cohort yielded a mean age of 70.6 years (range: 43–89 years), with 148 men and 11 women. The FLACS group had a mean age of 73.9 years (range: 52–89 years), with 41 men and 5 women. The high proportion of men was consistent with the institutional pattern of a predominantly male population at a veterans hospital. The differences of genders between the study cohorts were not

significant ($P=0.36$, Fisher's exact test). Due to the difference of mean ages ($P=0.01$, independent samples t -test), statistical significances (P) of mean operating time comparisons were calculated using a multivariable linear mixed-effects model controlling for age.

Observed preoperative nucleus grade was not statistically different between the cohorts, with a mean Lens Opacities Classification Grading System III (LOCS III) nuclear opalescence grade of 3.2 in the FLACS group and 3.1 in the conventional group ($P=0.32$, independent samples t -test). Use of iris expansion devices occurred in 9 cases of the conventional cohort, all involving insertion of a ring stabilizer (Malyugin Ring®; Microsurgical Technology, Redmond, WA, USA). No iris expansion devices were used in the FLACS group. Four additional cases with documented contraindications to FLACS were identified in the conventional group, including 2 patients with kyphosis, 1 patient with head tremor, and 1 case of traumatic zonular dialysis requiring capsular tension ring insertion.

Complications were documented in a total of 4 cases (2.0%), including 2 (1.3%) in the conventional phacoemulsification group and 2 (4.3%) among FLACS. Although the FLACS group had a higher percentage of complications, the difference could not be shown to be statistically significant ($P=0.22$, Fisher's exact test). Complications for the conventional phacoemulsification group were 1 case of posterior capsular tear with vitreous prolapse and 1 case of zonular dehiscence with vitreous prolapse. Complicated FLACS procedures were 2 cases of posterior capsular tear with vitreous prolapse. There were no cases of posteriorly dislocated lens material in either group. Isolated anterior capsule tear without other mishap occurred in 2 cases of the conventional cohort and in no cases of FLACS.

The results of operating time recordings are summarized in Table 1. Because sample sizes were large enough in each

group, 4 cases of anterior vitrectomy were censored and significance of interval differences were determined using a multivariable linear mixed-effects model, controlling for age and allowing random intercepts for each resident.

Total room time, total operation time, and corneal incision completion time were all found to be significantly longer in the laser group versus the conventional phacoemulsification group (each $P<0.05$). The mean difference in total operating time for the FLACS group was 7.37 minutes longer than the conventional group ($P=0.001$). Average total room time was 7.02 minutes longer in the FLACS groups ($P=0.02$). By contrast, the mean duration for anterior capsulotomy was significantly shorter in the femtosecond laser pretreatment group compared to conventional phacoemulsification ($P<0.001$).

There were no statistically significant differences between groups in the individual steps of nucleus removal, cortical removal, or IOL placement.

Discussion

Femtosecond laser cataract surgery technology has been integrated into the curricula of some ophthalmology residency programs, but this innovation does not yet have universal acceptance as an essential component of cataract surgery training. As with many ophthalmic procedures, FLACS is associated with a considerable learning curve as the surgeon progressively gains familiarity, but the technical difficulty encountered likely depends on the degree of background surgical expertise. Despite the challenges faced by experienced ophthalmologists, their learning process with FLACS is facilitated by an advanced foundation of microsurgical skills. By contrast, resident surgeons may face a particularly demanding learning curve when performing FLACS alongside their ongoing fundamental training

Table 1 Summary of performance time analysis of conventional phacoemulsification group and femtosecond laser pretreatment group

Interval	Conventional phacoemulsification		FLACS		Absolute difference		P-value
	M	SE	M	SE	M	SE	
Total OR time	68.59	5.66	75.61	6.08	7.02	3.02	0.02
Operative time	42.59	4.74	49.96	5.07	7.37	2.45	0.001
Incision	3.82	0.12	4.60	0.31	0.79	0.31	0.01
Anterior capsulotomy	3.23	0.18	1.38	0.15	1.84	0.42	<0.001
Nucleus removal	12.54	0.48	12.73	1.05	0.19	1.15	0.87
Cortical removal	5.37	0.27	6.17	0.86	0.80	0.71	0.26
IOL placement	0.93	0.05	0.96	0.11	0.02	0.12	0.86

Notes: All times are shown in minutes. Due to patients being nested within operating residents, significance (P -value) was determined using a multivariable linear mixed-effects model controlling for patient age and allowing random intercepts for each resident surgeon.

Abbreviations: FLACS, femtosecond laser-assisted cataract surgery; IOL, intraocular lens; M, mean; OR, operating room; SE, standard error of the mean.

in conventional phacoemulsification. Femtosecond laser learning experiences of well-established cataract surgeons have been described,^{2,7,10} but this report is the first published evidence specifically examining resident performance efficiency with FLACS.

At this institution, laser-assisted surgery is taught in conjunction with routine phacoemulsification at both PGY3 and PGY4 levels, with greater emphasis on FLACS during later stages of training. This study characterizes the comparative efficiencies of senior ophthalmology residents when performing FLACS, which was generally found to be less efficient than traditional surgery in the training program setting. Significantly longer times were demonstrated in association with FLACS for total OR time, microscope operating time, and corneal incision completion time. Interestingly, the difference of mean total room time only slightly exceeded the difference of mean operative time, suggesting that laser pretreatment did not substantially increase average room time. Extended time for femtosecond laser use could have been anticipated due to the 2-step nature of the procedure, but this study indicates that extension of the manual portion of the surgical procedure was the primary factor contributing to higher room times for FLACS cases. The source(s) of higher mean operative time in the FLACS group was not identified by our analysis of individual core steps, and the cause remains unclear. There are other procedural components not studied that might have contributed to decreased efficiency such as capsular staining dye use, viscoelastic injection, laser-generated gas bubble removal, hydrodissection, or confirmation of watertight wound closure. Additional non-technical factors that could potentially prolong FLACS OR times or procedure times include supervising attending instruction, patient restlessness, room design, operating table design, instrument access, duplication of time-out procedures, or lesser familiarity with FLACS by scrub technicians.

Although laser photophacofragmentation has been previously documented to reduce phacoemulsification power and time,^{1,5,11,12} our data did not show a benefit of reduced nucleus removal time. Our findings also did not demonstrate a significant difference for average cortical removal time, notwithstanding an anecdotal association of FLACS with increased technical difficulty with cortex aspiration.^{11,13,14} Despite similar perceptions at our institution, the collective data indicated that technical hindrances encountered during cortical cleanup did not systematically yield a longer mean time to accomplish this step.

Completion of capsulotomy with capsular leaflet removal was found to be shorter in the femtosecond laser group, but

this benefit was not associated with improved efficiencies of subsequent surgical steps by the resident FLACS trainees. Not surprisingly, we were unable to demonstrate shorter time for IOL placement with FLACS. However, other possible lens-related advantages of FLACS were not studied. Potential improvements of IOL position, centration, and anterior capsule overlap were beyond the scope of this study and have been reported elsewhere.^{15–17}

The FLACS group had a higher proportion of complications, but the difference of complication rate was not shown to be statistically significant with the sizes of the data sets. Both groups had complications occurring near or below reported rates of contemporary studies.^{18–22} Published reports of FLACS have described higher complications during early laser cases by experienced cataract surgeons,^{2,23} with a reduction of complications as surgeons accumulated more experience. A similar effect might be detected within training programs if residents were to complete more cumulative procedures. Higher laser case volumes would likely enable trainees to progress further along the FLACS learning curve, and trends toward improved safety and efficiency might be observed in further research involving a larger database. A multi-institutional, prospective, and randomized study conducted over a longer period of time would better characterize resident performance and outcomes.

Although analyses yielded statistically significant comparisons, this study was limited by the retrospective design and the availability of only 1 femtosecond laser device. The results of this study are specific to a single commercial laser platform, and cautious interpretation should be taken in generalization to the FLACS technology as a whole. Additionally, because randomization of case allocation was not possible, uncontrolled variables of the chart review had potential to affect comparisons across groups of patients and resident surgeons. Intrinsic selection biases herein are noteworthy. The conventional cohort included patients with contraindications to femtosecond laser treatment, particularly cases with mediocre pupil dilation, cornea opacification, or difficulty with supine patient positioning. Eyes with poor pupil dilation in our practice often required the additional operative steps of inserting and removing a pupil expansion device, which occurred in 9 of the conventional phacoemulsification cases and in none of the FLACS cases. Various other obstacles presented by some less common FLACS contraindications could also result in a need for additional surgical attention. In this study, examples included 4 cases in the conventional cohort involving patient kyphosis, head tremor, or capsular tension ring insertion. The inclusion of more challenging

cases in the conventional surgery group could be reasonably expected to result in longer mean surgical times and higher risk of complications, but such findings were not observed. Despite laser pretreatment and deselection of complex cases, average total “cut” time used to complete the procedure under the operating microscope was found to be longer for the FLACS cohort. This phenomenon has not been previously described and is best explained by resident learning curve to address necessary modifications of manual phacoemulsification resulting from the laser pretreatment.

The role of FLACS in ophthalmology resident education is evolving, as is the role of this technology in general practice. Regardless of efficiency reductions during early trainee cases, inclusion of FLACS in teaching curriculum provides for a more comprehensive surgical experience to prepare residents for future practice. Additionally, FLACS appears to improve efficiency of anterior capsulotomy, a critical portion of the procedure that is widely considered the most hazardous step for trainees. The findings of this study and previously reported data⁵ support the concept that automated anterior capsulotomy with FLACS may eventually emerge as a better solution in cataract surgery learning for residents in the future.

Conclusion

There is a potential for longer FLACS operative times by senior residents when training programs are introducing femtosecond laser technology into residency curricula, with complications among FLACS cases occurring close to expected trainee rates for conventional phacoemulsification.

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Disclosure

The authors report no conflicts of interest in this work.

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