Resident-Performed Selective Laser Trabeculoplasty in Patients With Open-Angle Glaucoma

Daniel A. Greninger, MD; Eugene A. Lowry, BA; Travis C. Porco, PhD, MPH; Ayman Naseri, MD; Robert L. Stamper, MD; Ying Han, MD, PhD

IMPORTANCE To our knowledge, this is the first study to investigate effectiveness and complication rates of resident-performed selective laser trabeculoplasty (SLT).

OBJECTIVES To evaluate the effectiveness and complications of SLT performed by resident ophthalmologists and to identify predictors for success.

DESIGN, SETTING, AND PARTICIPANTS Retrospective case series of 81 patients with open-angle glaucoma undergoing 110 SLT procedures from November 17, 2009, through December 16, 2011, at the San Francisco Veterans Affairs Medical Center.

INTERVENTION Resident-performed SLT.

MAIN OUTCOMES AND MEASURES Intraocular pressure (IOP) reduction. Secondary outcomes included change in eyedrop medications, complication rates, and predictors of SLT success defined as a 20% reduction in IOP.

RESULTS The mean IOP at baseline, defined as the average IOP of the 2 appointments prior to the SLT procedure, was 18.7 mm Hg. The mean decrease in postoperative IOP compared with baseline was 2.2 mm Hg (12%; 95% CI, 5%-19%) at 12 months and 3.3 mm Hg (18%; 95% CI, 13%-23%), 2.8 mm Hg (15%; 95% CI, 10%-21%), and 3.6 mm Hg (19%; 95% CI, 11%-27%) at 3, 6, and 24 months, respectively (all P < .001, linear mixed-effects regression). Success rates were 36% (95% CI, 27%-47%) at 12 months and 41% (95% CI, 31%-53%), 50% (95% CI, 40%-60%), and 39% (95% CI, 26%-53%) at 3, 6, and 24 months, respectively. The most common complication was a temporary IOP spike, with increases of at least 6 mm Hg occurring in 7% (95% CI, 4%-14%) of the population. The largest IOP spike was 11 mm Hg. Increased number of laser shots performed was not associated with better IOP control but was associated with a reduction in number of eyedrop medications (P = .02). Increased baseline IOP was associated with an odds ratio for success of 1.24 (95% CI, 1.08-1.44) at 3 months, 1.20 (95% CI, 1.05-1.37) at 6 months, and 1.31 (95% CI, 1.13-1.53) at 12 months of follow-up (P = .003, P = .006, and P < .001, respectively, logistic regression). In a multivariate analysis, baseline IOP remained the greatest predictor of effectiveness.

CONCLUSIONS AND RELEVANCE Resident-performed SLT obtains outcomes similar to the IOP reduction reported in the literature for attending-performed SLT with low levels of complications. Increasing the number of shots in a treatment session may lead to less long-term need for eyedrop medications. In this patient group, higher baseline IOP was the strongest predictor of treatment effectiveness.

Author Affiliations: Department of Ophthalmology, Oregon Health and Science University, Portland (Greninger); Department of Ophthalmology, University of California, San Francisco (Greninger, Lowry, Porco, Naseri, Stamper, Han); Division of Preventive Medicine and Public Health, Department of Epidemiology and Biostatistics, University of California, San Francisco (Porco); Francis I. Proctor Foundation, University of California, San Francisco (Porco, Naseri, Han); Department of Ophthalmology, San Francisco VA Medical Center, San Francisco, California (Naseri, Stamper, Han).

Corresponding Author: Ying Han, MD, PhD, Department of Ophthalmology, University of California, San Francisco, 10 Koret Way, San Francisco, CA 94143 (ying.han@ucsf.edu).

Published online January 16, 2014.

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Selective laser trabeculoplasty (SLT) is increasingly used as a treatment for open-angle glaucoma in adults. It has replaced argon laser trabeculoplasty in many practices. The procedure is reported to result in a decrease in intraocular pressure (IOP) of approximately 20% with a good adverse effects profile. The maximum IOP-lowering effect is thought to be found after 6 weeks, with decreasing effectiveness thereafter.

The effectiveness and safety of resident-performed ophthalmic surgery has been reported in multiple subspecialty areas. There have been 2 previous reports detailing outcomes of resident-performed argon laser trabeculoplasty, but to our knowledge, outcomes from resident-performed SLT have not yet been examined.

In the Department of Ophthalmology at the University of California, San Francisco, first-year residents rotating through the San Francisco Veterans Affairs (VA) Medical Center perform all laser trabeculoplasty operations. Since November 2009, all laser trabeculoplasties have been performed as SLT. The purpose of this study was to evaluate the effectiveness and complications of resident-performed SLT. Additionally, predictors of effectiveness were sought to improve clinical practice.

Methods

Permission was obtained from the Research and Development Committee at the San Francisco VA Medical Center and the University of California, San Francisco Institutional Review Board to perform the study. As the study was retrospective, informed consent for study participation was not feasible to obtain and a waiver was granted by the institutional review board.

Consecutive patients treated with SLT by resident ophthalmologists at the San Francisco VA Medical Center during a 2-year period from November 17, 2009, to December 16, 2011, were identified from laser log books and by the retrospective review of scheduling logs for the glaucoma laser clinic. Exclusion criteria included attending physician participating directly in the procedure, inadequate charting, and patients who had no follow-up visits after treatment. Each included patient in the study had been previously examined by an attending glaucoma specialist (R.L.S., Y.H.) and had been referred for SLT to be performed by a resident ophthalmologist. Residents were divided between those having prior experience with laser trabeculoplasty at other hospitals and those performing their first glaucoma laser procedures. All laser operations were performed under the supervision of an attending physician, and each resident worked under the direct observation of an attending glaucoma specialist through the assistant scope until the resident felt comfortable to perform the procedure alone.

Typically, patients received 1 drop of topical proparacaine hydrochloride and apraclonidine hydrochloride, 0.5%, in the operative eye before surgery. Visual acuity and preoperative IOP were recorded before eyedrops were administered. For some patients, pilocarpine hydrochloride was added to improve the visualization of angle structures. A Latina SLT lens was placed on the operative eye with hydroxypropyl methylcellulose and laser treatment was applied. One drop of apraclonidine hydrochloride, 0.5%, was administered after the procedure. Postoperative IOP was checked approximately 1 hour after the procedure, 6 weeks after the procedure, and at regular intervals thereafter as indicated by the clinical history. Patient records were followed up for 2 years, until the end of the study, or until the patient underwent glaucoma surgery, whichever came first. The IOP was measured by Goldmann applanation in most patients.

Treatment success was defined as a 20% reduction in IOP from baseline, which was defined to maintain consistency with the attending literature as the average IOP of the 2 appointments prior to the SLT procedure. The IOP was compared for a difference between baseline and treatment day using the clustered Wilcoxon signed rank test, accounting for statistical correlation between the 2 eyes of a given patient. Change measurements were calculated using linear mixed-effects regression and included reduction in IOP, change in number of different medications (eyedrops) in use following surgery, and visual acuity. The 95% confidence intervals were calculated with binomial confidence intervals using the methods recommended by Agresti and Coull. Logistic regression was used to perform univariate and multivariate analysis of potential predictors of treatment success, including baseline IOP, right or left eye, age, number of treatment shots, number of different medications (eyedrops) in use on the day of surgery, treatment day IOP, treatment total power, the number of angular degrees treated, operator experience, and whether the operation was a first or repeated SLT. The P values calculated for these potential predictors of treatment success were adjusted with a Holm-Bonferroni correction for multiple comparisons at our 12-month primary outcome end point. An analysis of loss to follow-up comparing clinical characteristics of the baseline treated population with those at each follow-up appointment was performed with the Welch heteroscedastic t test (age, treatment day IOP, and number of shots) or the Wilcoxon rank sum test (number of different medications in use on the day of surgery). All clustered analyses were validated with a repeated analysis including only 1 eye per patient, which yielded no significant changes in results and conclusions. Analyses were conducted with R version 2.14 statistical software for Macintosh (R Foundation).

Results

A total of 118 procedures in 87 patients were reviewed. Eight procedures in 6 patients met exclusion criteria: 5 patients and 7 procedures for no follow-up and 1 patient with 1 procedure for inadequate charting. The remaining 110 procedures in 81 patients were included in the analysis. Patients had a mean age of 74.1 years, they were predominantly male, and most had a diagnosis of primary open-angle glaucoma (Table 1). Most patients underwent SLT in only 1 eye, although 36% received
treatment for both eyes during the study period and 6% underwent re-treatment on the same eye.

One hundred ten SLT procedures were performed during the study period. The mean number of shots performed was 94.3, at a mean power of 0.81 mJ for a mean total power of 76.5 mJ (Table 2). Most patients received either 180° treatment (53% of patients) or 360° treatment (38% of patients), with most of the 180° treatments occurring in the first year of study and most of the 360° treatments occurring in the second year. The 360° treatment group received approximately twice the shots per treatment, leading to a nearly identical ratio of shots per degree of treatment between the 2 groups.

The mean baseline IOP was 18.7 mm Hg; the mean number of different eyedrop medications at baseline was 2.6 (95% CI, 2.4–2.8). The mean IOP then decreased to 18.1 mm Hg on the day of SLT (P = .19, clustered Wilcoxon signed rank test), which was on average 58.4 days after the referral appointment. The mean decrease in postoperative IOP compared with baseline was 2.2 mm Hg (95% CI, 1.0–3.3) at 12 months and 3.3 mm Hg (95% CI, 2.4–4.3), 2.8 mm Hg (95% CI, 1.8–3.8), and 3.6 mm Hg (95% CI, 2.0–5.1) at 3, 6, and 24 months, respectively (all P < .001, linear mixed-effects regression) (Figure 1). Successful treatment, defined as a 20% IOP reduction, was achieved in 36% (95% CI, 27%–47%) of patients followed up at 12 months and 41% (95% CI, 31%–53%), 50% (95% CI, 40%–60%), and 39% (95% CI, 26%–53%) of patients at 3, 6, and 24 months, respectively. There was no difference between the baseline cohort and follow-up cohorts at 1, 3, 6, 12, and 24 months in terms of age, baseline IOP, or number of treatment eyelids (all P > .20), although the 24-month follow-up cohort had significantly reduced treatment shots (P < .001) (Table 3).

Univariate and multivariate analyses both showed baseline IOP to be the greatest predictor of procedural success. Baseline IOP was associated with odds ratios of 1.24 (95% CI, 1.08–1.44; P = .003), 1.20 (95% CI, 1.05–1.37; P = .006), and 1.31 (95% CI, 1.13–1.53; P < .001) for success with each 1-mm Hg in-

### Table 1. Baseline Characteristics of Patients Included in Studya

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>74.1 (10.5)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>78 (96)</td>
</tr>
<tr>
<td>Female</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Type of treatment</td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td>52 (64)</td>
</tr>
<tr>
<td>Bilateral</td>
<td>29 (36)</td>
</tr>
<tr>
<td>Type of glaucoma</td>
<td></td>
</tr>
<tr>
<td>Primary open angle</td>
<td>71 (88)</td>
</tr>
<tr>
<td>Pseudoexfoliation</td>
<td>5 (6)</td>
</tr>
<tr>
<td>Pigment dispersion</td>
<td>3 (4)</td>
</tr>
<tr>
<td>Normal tension</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Traumatic</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

*a Most patients were men with primary open-angle glaucoma who had selective laser trabeculoplasty in only 1 eye during the study period.

### Table 2. Characteristics of the Selective Laser Trabeculoplasty Treatments

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shots, mean (SD), No.</td>
<td>94.3 (49.0)</td>
</tr>
<tr>
<td>Power/shot, mean (SD), mJ</td>
<td>0.81 (0.12)</td>
</tr>
<tr>
<td>Total power, mean (SD), mJ</td>
<td>76.5 (44.4)</td>
</tr>
<tr>
<td>Angle, No. (%)</td>
<td></td>
</tr>
<tr>
<td>180°</td>
<td>58 (33)</td>
</tr>
<tr>
<td>270°</td>
<td>1 (1)</td>
</tr>
<tr>
<td>360°</td>
<td>42 (38)</td>
</tr>
<tr>
<td>Unknown</td>
<td>9 (8)</td>
</tr>
<tr>
<td>Re-treatment, No. (%)</td>
<td>5 (4)</td>
</tr>
</tbody>
</table>

A total of 15 residents performed the laser procedures described earlier. Ten of these residents, corresponding to 79 SLT procedures, had experience with SLT at a different hospital prior to performing the SLT procedures in this study. The remaining 5 residents, corresponding to 31 SLT procedures, had no experience before the SLT cases performed in this study. Success rates were similar between the 2 groups, with respective success rates of 40%, 52%, and 37% for the more experienced group at 3, 6, and 12 months compared with 45%, 43%, and 35% for the less experienced (P = .79, P = .62, and P > .99, respectively).

Complications from treatment were generally infrequent. A postprocedure IOP spike of at least 6 mm Hg after SLT treatment was seen in 8 procedures (7%; 95% CI, 4%–14%) of our study population (5 with 180° treatment and 3 with 360° treatment). The greatest IOP spike observed was 11 mm Hg. None of these patients required additional surgical treatment to control SLT-induced IOP elevation. There was 1 case of cystic macular edema following 360° SLT, and 1 case of a corneal epithelial defect from the Latina lens resulted in a patient visit to the emergency department for after-hours pain relief. There was no significant change in visual acuity measured 12 months after treatment (P = .59, clustered Wilcoxon signed rank test) or with increasing treatment (P = .79, linear mixed-effects regression).

### Discussion

The first aim of this study was to evaluate the effectiveness of resident-performed SLT. We chose our baseline to be consis-
tent with attending studies, which generally define baseline IOP over 1 or 2 appointments before the treatment day.\textsuperscript{10-14,17} We found a significant decrease from baseline to all points in follow-up. There was an 18\% mean decrease in IOP at 3 months, which was maintained at 24 months after the procedure. The published results for attending-performed SLT operations in the literature varied, with 1 study showing an average 18\% IOP reduction out to 6 months and another showing a 32\% reduction at 5 years.\textsuperscript{11,14} Most previous studies that we reviewed showed IOP reductions ranging from approximately 20\% to 30\% from baseline over a year of follow-up, with baseline IOPs that vary from 24 to 27 mm Hg.\textsuperscript{10-14,17} Our results for IOP reduction are at the low end of the attending literature, while our baseline IOP is well below the range reported in attending studies. As baseline IOP is the primary predictor for extent of IOP reduction, we believe these results provide evidence that resident- and attending-performed SLTs are of comparable effectiveness.

Our second aim was to investigate complication rates. Although direct comparisons are complicated by different adjuvant medications and IOP elevation thresholds, our IOP spike rate of 7\% compares favorably to studies done elsewhere reporting a postprocedure spike of at least 8 mm Hg in 9\% to 13\% of patients.\textsuperscript{12,18} We found no evidence of decreased visual acuity.

Another aim was to examine whether prior resident experience had any effect on outcomes. The proportion of SLT operations achieving success was similar between those performed by residents with and without previous experience. There was no consistent trend favoring success in either experience group over the observed follow-up period and no statistical difference at any point in follow-up, although we have limited power to detect such a difference in our sample size. The average number of laser trabeculoplasty operations performed by residents during training, based on Accreditation Council for Graduate Medical Education case log data, was 10.2 in 2010 to 2011, with a maximum of 78 procedures and a median of 7. In our study, the more experienced residents performed an estimated 10 procedures before their experience at the San Francisco VA Medical Center. Therefore, these data give the first suggestion that there is likely not a specific need to increase the amount of laser trabeculoplasty training performed during residency beyond the current national average to improve
outcomes, and they suggest that residents in training do not provide inferior treatment.

A final aim of the study was to evaluate predictors for treatment success. Overall, we saw a success rate of 36% at 12 months. The greatest predictor of successful outcome in our cohort was higher IOP at baseline, with odds ratios of success at 12 months of 1.31 and 1.26 associated with each point increase in baseline IOP in univariate and multivariate analysis, respectively. This is consistent with previous reports.19-21

We did not find a direct effect of number of shots on IOP in our follow-up period but found that number of shots did predict lower numbers of topical medications at 6 and 12 months with a trend toward significance at 3 and 24 months. Previous studies have noted a greater decrease in IOP with increased SLT treatment degree as well as reductions in IOP fluctuations.21,22 We anticipated this effect with treatment shots as the number of shots scaled linearly with the degrees treated in our patient population and postulate that this expected effect was confounded in our population by medication changes. Physicians may have responded to lower and relatively stable IOPs by weaning patients off medication, while maintaining or increasing medications in less stable patients to achieve the same IOP goals. Thus, we find that the extent of treatment in our study led to reduction in use of eyedrop medications rather than reduction in IOP.

This study had several limitations. The study was retrospective and is subject to the usual limitations of retrospective studies, including differential medical management of study participants according to their disease history. Because the study was conducted at a VA hospital, most patients were male. In our study, not all patients had a predetermined IOP goal at the time of SLT. We are therefore unable to assess factors that predict success defined by meeting target IOP and limit our definition of success to 20% IOP reduction from baseline. Patients at lower baseline IOP may reach target IOP goals but without achieving a 20% IOP reduction. Additionally, the lack of masking may have led to an observer bias if physician expectation of lower IOP after SLT altered their observed measurements. The IOP measurements in this study were taken during clinic business hours but were not controlled more specifically for time of day, which may have contributed to fluctuations.23 We included different eyes in the same patients, which we attempted to control for with clustered analysis to account for the statistical correlation between 2 eyes in a given patient. Most IOP measurements were obtained using Goldmann applanation tonometry (92%); however, pneumotonometry (2%) and the Tono-Pen (7%) were used in a small number of cases and this variability could have affected the results.

In summary, resident-performed SLT appears to be effective with a low complication profile. There was no evidence of a difference between resident performance on their first cases compared with later cases, indicating that, under attending guidance, safety and effectiveness may be maintained in even the earliest procedures of training. Patients with a higher baseline IOP are most likely to receive benefit from the procedure. Those patients receiving higher levels of treatment may be able to reduce their medication burden. Given the complication and effectiveness profile of this treatment, resident-performed SLT may be considered a potential early-line therapy for patients with open-angle glaucoma and difficulty with medication adherence.
ARTICLE INFORMATION

Submitted for Publication: May 9, 2013; final revision received August 3, 2013; accepted August 13, 2013.

Published Online: January 16, 2014.

Author Contributions: Drs Greninger and Han and Mr Lowry had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Dr Greninger and Mr Lowry contributed equally to this work and are co–first authors. Study concept and design: Greninger, Lowry, Naseri, Stamper, Han.

Acquisition of data: Greninger, Lowry.

Analysis and interpretation of data: Greninger, Lowry, Porco, Naseri, Han.

Drafting of the manuscript: Greninger, Lowry, Han.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Lowry, Porco, Han.

Administrative, technical, and material support: Greninger, Lowry, Stamper, Han.

Study supervision: Naseri, Stamper, Han.

Conflict of Interest Disclosures: None reported.

REFERENCES


