
The outcomes of selective laser trabeculoplasty at six months

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Abstract

Purpose: To study the intraocular pressure (IOP)-lowering effects of selective laser trabeculoplasty (SLT) at six months and to determine factors that can predict the success of SLT.

Study design: Prospective cohort study with convenience sampling.

Material and methods: The patients were seen at the Glaucoma Clinic, Selayang Hospital from October 2017 to September 2018. Patients with primary open-angle glaucoma (POAG), normal-tension glaucoma (NTG), and ocular hypertension (OHT) of mild to moderate severity that needed further IOP reduction were recruited. Baseline characteristics were documented followed by water drinking test (WDT) and SLT. Follow-up was scheduled at one week, six weeks, three months, and six months. WDT was repeated at six months.

Results: Eighteen eyes of 18 patients were recruited. IOP at baseline, 1 week, 6 weeks, 3 months, and 6 months was 19.3 ± 3.7 , 16.7 ± 3.8 , 16.5 ± 2.7 , 16.6 ± 3.2 and 15.3 ± 3.8 mmHg, respectively ($P < 0.05$). The reduction of baseline IOP, peak IOP, and IOP fluctuation were 20.7%, 26.7%, and 31.4%, respectively ($P < 0.05$). The cumulative success at six months was 44%. The significant success predictors were mean deviation on Humphrey visual field and IOP one week post-SLT.

Conclusions: SLT can be used to treat mild to moderate POAG, NTG, and OHT patients, either as first-line treatment or as an adjunct to medical therapy.

Keywords: intraocular pressure, glaucoma, selective laser trabeculoplasty, success predictor, water drinking test

Dapatan kajian trabekuloplasti laser selektif pada enam bulan

Abstrak

Tujuan: Untuk mengkaji kesan tekanan intraokular (IOP) dari laser selektif trabekuloplasti (SLT) pada enam bulan dan untuk menentukan faktor-faktor yang dapat meramalkan kejayaan SLT.

Reka bentuk kajian: Kajian kohort prospektif dengan pensampelan mudah.

Bahan dan kaedah: Melibatkan pesakit yang dirawat di Klinik glaukoma, Hospital Selayang dari Oktober 2017 hingga September 2018. Pesakit dengan glaukoma sudut terbuka primer (POAG), glaukoma tekanan normal (NTG), dan hipertensi okular (OHT) peringkat ringan hingga sederhana teruk yang memerlukan pengurangan IOP telah direkrut. Ciri-ciri asas didokumentasikan diikuti dengan ujian minum air (WDT) dan SLT. Tindakan susulan dijadualkan pada satu minggu, enam minggu, tiga bulan, dan enam bulan. WDT diulang pada enam bulan.

Dapatan: Lapan belas mata dari 18 pesakit direkrut. IOP pada garis awal, 1 minggu, 6 minggu, 3 bulan, dan 6 bulan selepas SLT adalah 19.3 ± 3.7 , 16.7 ± 3.8 , 16.5 ± 2.7 , 16.6 ± 3.2 dan 15.3 ± 3.8 mmHg ($p < 0.05$). Pengurangan IOP dari garis asas, puncak IOP, dan IOP fluktuasi masing-masing ialah 20.7%, 26.7%, dan 31.4% ($p < 0.05$). Kejayaan kumulatif pada enam bulan adalah 44%. Peramal kejayaan yang ketara adalah penyimpangan min pada medan visual Humphrey dan IOP satu minggu selepas SLT.

Kesimpulan: SLT boleh digunakan untuk merawat tahap awal dan sederhana pesakit POAG, NTG, dan OHT, sama ada sebagai rawatan peringkat pertama atau sebagai tambahan kepada terapi secara perubatan.

Kata kunci: glaukoma, laser selektif trabekuloplasti, peramal kejayaan, tekanan intraokular, ujian minum air

Introduction

Selective laser trabeculoplasty (SLT) was introduced by Latina and Park in 1995.¹ It works by selectively targeting the pigmented trabecular meshwork (TM) to increase aqueous outflow by mechanical² and cellular mechanisms.³ The intraocular pressure (IOP)-lowering effect of SLT has been evaluated by numerous researchers with promising results. It was reported to be comparable to medical therapy^{4,5} and has the potential to be the first-line treatment in the management of glaucoma. SLT avoids the issues of side effects, compliance, and cost related to medications, and it does not come with the risks associated with glaucoma surgery.

SLT success rates have been reported to vary from 40% to 84% in patient groups of different characteristics.⁶⁻⁸ Much work has been done to identify the predicting factors for SLT success. Some researchers found high baseline IOP⁹ and an absence of antiglaucoma medications¹⁰⁻¹² to be associated with success of SLT treatment, whereas factors such as age, sex, and diabetes mellitus were not consistent.

The role of IOP-lowering in delaying the progression of optic nerve damage is undebatable.¹³⁻¹⁵ However, large diurnal fluctuations in IOP and IOP peaks that are not detected during office hours also contributes to the progression of glaucoma.¹⁶ The water drinking test (WDT) has been proposed as a useful test to predict IOP peaks and fluctuations in the clinical setting.^{16,17} IOP peaks detected during the WDT have a strong association with the severity of visual field defect and may be predictive of glaucoma progression.¹⁶

In this study, we aimed to study the IOP-lowering effect of SLT at six months and to determine factors that can predict its success. We also assessed the efficacy and sustainability of SLT in reducing IOP peaks and fluctuation using the WDT.

Materials and methods

This prospective cohort study recruited patients from the Glaucoma Clinic, Selayang Hospital from October 2017 to September 2018. The convenience sampling method was used. Approval from the Clinical Research Centre, Selayang Hospital, National Medical Research Registry (NMRR) and Medical Research Ethics Committee (MREC) were obtained and the study conformed to the tenets of the Declaration of Helsinki. Informed consent forms from all participants were signed before the study started.

Patients with ocular hypertension (OHT), normal-tension glaucoma (NTG), and primary open-angle glaucoma (POAG) of early or moderate disease with cup-disc ratio (CDR) 0.8 or less and mean deviation (MD) less than -12.0 dB, that required further reduction of IOP were included. Patients with IOP more than 30 mmHg, history of glaucoma surgery or laser trabeculoplasty, history of uveitis, patients with chronic kidney disease or cardiac failure, patients who were on diuretics or patients who were unable to consume the required volume of fluid within five minutes were excluded. For patients who had SLT in both eyes, the eye with higher baseline IOP was taken as the study eye.

On the first visit, baseline characteristics (age, gender, race, type of glaucoma, number of antiglaucoma medications, central corneal thickness [CCT], CDR, MD on Humphrey visual field [HVF], visual acuity) were taken. Baseline IOP was taken, followed by the WDT. SLT was performed after the WDT. IOP was measured again one-hour post-SLT. Follow-ups were scheduled at one week, six weeks, three months, and six months. WDT were repeated at six months.

SLT

SLT was performed by the author following WDT during first visit. It was performed using a Q-switched Nd:YAG laser (Ellex Solo, Ellex, Mawson Lakes, Australia) under topical anaesthesia using a Latina lens. Power was started at 0.5 mJ and titrated until bubble formation was just visible. One hundred contiguous, non-overlapping shots were placed onto 360° of the TM. All patients were treated with ketorolac eyedrops four times a day for one week post-SLT.

WDT

The WDT is an alternative measure that can be done during office hours to evaluate the aqueous outflow facility reserve and efficacy of the TM. In this study, patients were instructed not to ingest any fluid within two hours before the WDT. During the first visit, each patient was required to drink 10ml/kg of body weight of drinking water within five minutes after measuring baseline IOP. Then, IOP was measured four times at 15-minute intervals. The highest value was taken as the peak IOP. The difference between baseline IOP and peak IOP is noted as fluctuation. IOP measurements were done with a Goldmann applanation tonometer AT 900 (Haag-Streit, Koniz, Switzerland).

Statistical analysis

The primary outcome was successful IOP reduction at six months. Successful SLT was defined as IOP reduction $\geq 20\%$ of baseline IOP. The secondary outcomes were possible predictors of success, which were compared between the success and non-success groups.

The sample size was calculated using PS Power and Sample Size Calculator version 3.1.2 (Department of Biostatistics and Vanderbilt University School of Medicine, USA). A total of 16 patients was required. In order to allow a dropout rate of 20%, 20 patients were recruited. Statistical analysis was performed using Statistical Package for Social Science (SPSS for MAC version 21.0, SPSS Inc., Chicago, USA). For numerical variables, the independent t-test and Mann-Whitney U test were used to detect statistical significance; for categorical variables, Fisher's exact test was used. Paired sample t-test was used for continuous data, *i.e.* to compare baseline IOP pre- and post-SLT, and IOP peak and fluctuation pre- and post-SLT. A *P* value < 0.05 was considered statistically significant. Univariate logistic regression analyses were performed for the possible predictors of success and any factors with *p*-value close to 0.05 were included in multivariate regression analysis.

Results

Twenty patients were recruited in total. One patient defaulted follow-up and another patient was prescribed new antiglaucoma drops, hence they were excluded

Table 1. Baseline characteristics and demographic data

Number of eyes	18
Age (years), median, IQR	62.5, 15
Gender, n (%)	
- Female	10 (55.6)
- Male	8 (44.4)
Race, n (%)	
- Malay	6 (33.3)
- Chinese	11 (61.1)
- Indian	1 (5.6)
Diabetes mellitus, n (%)	
- yes	10 (55.5)
- no	8 (44.5)
Hypertension, n (%)	
- yes	10 (55.5)
- no	8 (44.5)
Glaucoma type, n (%)	
- POAG	5 (27.8)
- NTG	9 (50.0)
- OHT	4 (22.2)
Antiglaucoma medications, n (%)	
- 0	14 (77.8)
- 1	1 (5.6)
- 2	2 (11.1)
- 3	0 (0)
- 4	1 (5.6)
Baseline IOP, mmHg, mean \pm SD	19.3 \pm 3.7
CCT (mm), mean \pm SD	548.3 \pm 30.80
MD, mean \pm SD	- 4.1 \pm 2.96
CDR, median, IQR	0.7, 0.2

CDR: cup-disc ratio; CCT: central corneal thickness; IOP: intraocular pressure; MD: mean deviation; NTG: normal-tension glaucoma; OHT: ocular hypertension; POAG: primary open-angle glaucoma; SLT: selective laser trabeculoplasty

from the study. Eighteen eyes of 18 patients were included in the study analysis. The baseline characteristics and demographic data of the patients are shown in Table 1.

IOP lowering effects of SLT

The baseline IOP was 19.3 ± 3.7 mmHg. IOP increased to 23.4 ± 4.3 mmHg one hour post-SLT. However, IOP decreased below baseline level as soon as one week post-SLT and was maintained throughout the follow-up period (Table 2).

SLT significantly reduced the baseline IOP, peak IOP, and IOP fluctuations at six months post-treatment. There was a 20.7% drop in baseline IOP and a 26.7% drop in peak IOP. SLT also reduces IOP fluctuations from 5.1 mmHg to 3.5 mmHg, which is equivalent to a 31.4% reduction (Table 3).

Table 2. IOP pre- and post-SLT

Duration	IOP (mmHg), mean \pm SD
Baseline	19.3 ± 3.7
1 hour post-SLT	23.4 ± 4.3
1 week post-SLT	16.7 ± 3.8
6 weeks post-SLT	16.5 ± 2.7
3 months post-SLT	16.6 ± 3.2
6 months post-SLT	15.3 ± 3.8

* $p < 0.05$ when baseline IOP was compared to all timepoints post-SLT treatment, except one hour post-SLT (general linear model, repeated measure)

Table 3. Comparison of baseline IOP, peak IOP, and IOP fluctuation between pre-SLT and six months post-SLT

	Pre-SLT ($n = 18$)		Post-SLT ($n = 18$)		% Mean IOP reduction	P-value
	Mean IOP (mmHg)	Standard deviation	Mean IOP (mmHg)	Standard deviation		
Baseline IOP	19.3	3.7	15.3	3.8	20.7	0.000
Peak IOP	24.3	4.4	18.8	3.5	26.7	0.000
IOP fluctuation	5.1	2.7	3.5	1.4	31.4	0.037

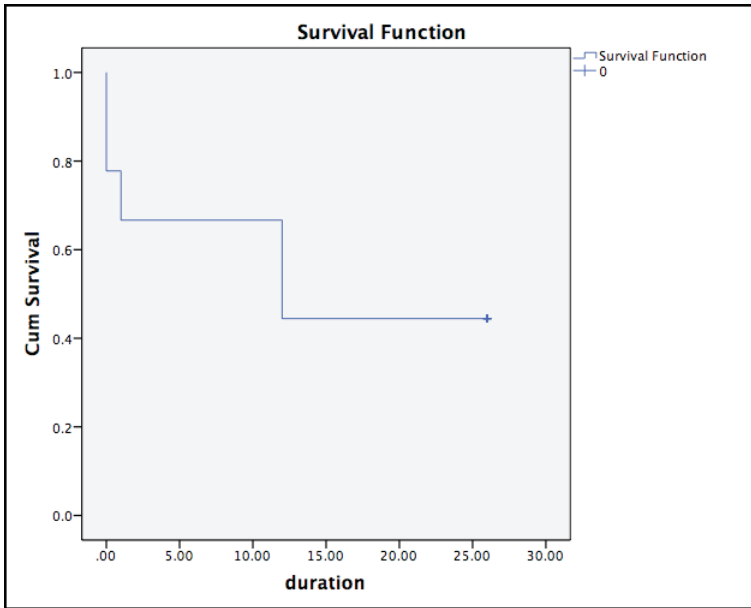


Fig. 1. Cumulative success rates.

Table 4. Baseline and post-SLT IOP in the success and non-success groups

Duration	Success*	Non-success	P-value
Baseline	20.1 ± 3.9	18.6 ± 3.6	0.402
1 hour	25.1 ± 4.3	22.1 ± 3.9	0.139
1 week	16.0 ± 4.7	17.3 ± 3.0	0.488
6 weeks	16.1 ± 3.1	16.8 ± 2.5	0.620
3 months	16.6 ± 3.5	16.6 ± 3.1	0.987
6 months	13.0 ± 2.1	17.1 ± 3.8	0.016

* $p < 0.05$ when baseline IOP was compared to all timepoints post-SLT treatment (general linear model, repeated measure)

The cumulative success at six months was 44% (Fig. 1).

IOP in the success group showed significant reduction as early as one week post-treatment and dropped further at six months. In the non-success group, there was no significant IOP reduction at any of the follow-up timepoints. IOP reduction at all timepoints post-treatment was statistically significant when compared to baseline IOP (Table 4).

Predictors of SLT success

The predictors of success of SLT under study were age, gender, race, diabetes mellitus, hypertension, type of glaucoma, number of glaucoma medications, baseline IOP, MD, CCT, CDR, visual acuity in logMAR, and IOP one week post-SLT (Table 5). Although the success group included older age, more antiglaucoma medications, higher baseline IOP, thinner CCT, and higher CDR, these factors were not statistically significant between the success and non-success groups. The significant predictors were MD and percentage of IOP reduction at one week post-treatment. The mean MD for the success group was -5.69 ± 3.59 , whereas for the non-success it was $-2.78 \pm$

Table 5. Comparison of the success and non-success groups

Variable	Success	Non-success	P-value
Age (years), median, IQR	67.0, 14	57.4, 14	0.083*
Gender (female/ male)	3/5	5/5	0.664 [^]
Race, n			0.472 [^]
- Malay	3	3	
- Chinese	4	7	
- Indian	1	0	
Diabetes mellitus, n (Y/N)	5/3	5/5	0.664 [^]
Hypertension, n (Y/N)	4/4	6/4	1.000 [^]
Glaucoma type, n			0.827 [^]
- POAG	3	2	
- NTG	4	5	
- OHT	1	3	
Antiglaucoma medications, n			0.127*
- 0	5	9	
- 1	0	0	
- 2	2	0	
- 3	0	0	
- 4	1	0	
Baseline IOP, mmHg, mean \pm SD	20.1 \pm 3.9	18.6 \pm 3.6	0.402**
CCT (mm), mean \pm SD (range)	539.4 \pm 30.9	555.5 \pm 30.3	0.282**
MD, mean \pm SD (range)	-5.69 \pm 3.59	-2.78 \pm 1.53	0.034**
CDR, median, IQR	0.80, 0.2	0.70, 0.2	0.194*
logMar, median, IQR	0.18, 0	0.18, 0	0.735*
1-week IOP reduction (%), mean \pm SD	20.9 \pm 15.0	6.0 \pm 11.1	0.028**

*Mann Whitney U test; **independent t-test; [^]Fisher's exact

CDR: cup-disc ratio; CCT: central corneal thickness; IOP: intraocular pressure; MD: mean deviation; NTG: normal-tension glaucoma; OHT: ocular hypertension; POAG: primary open-angle glaucoma; SLT: selective laser trabeculoplasty

Table 6. Univariate and multivariate regression analyses of the covariates affecting SLT success

	Univariate logistic regression		Multiple regression	
	P-value	Odds ratio	P-value	Odds ratio
Age	1.038	0.428		
Gender	0.597	1.667		
Race	1.000	0.000		
Diabetes mellitus	0.597	0.600		
Hypertension	0.672	1.500		
Glaucoma type	0.307	4.500		
Number of medications	0.163	3.440		
Baseline IOP	0.382	1.130		
CCT	0.272	0.980		
MD	0.068	0.630	0.114	0.177
CDR	0.563	5.610		
Visual acuity	0.873	0.520		
1-week IOP reduction (%)	0.068	0.900	0.094	0.777

CDR: cup-disc ratio; CCT: central corneal thickness; IOP: intraocular pressure; MD: mean deviation

1.53 ($p < 0.05$). The success group demonstrated 20.9% of IOP reduction at one week post-treatment compared to a 6% reduction in the non-success group.

Using univariate and multivariate analysis, none of the covariates were significantly associated with SLT success (Table 6).

Discussion

SLT is a relatively safe, easy-to-perform office procedure to lower IOP. In terms of SLT efficacy, our study demonstrated a 4.0 mmHg reduction of IOP and a cumulative success of 44% at six months post-SLT treatment. While the IOP reduction is comparable, our success rate is slightly lower than that published in a review showing a 3.8 to 8 mmHg reduction in IOP and a 55-82% success rate between 6 to 12 months.¹⁸ In this review article, the pre-SLT IOP ranged from 23 mmHg to 26 mmHg, whereas our baseline IOP was 19.3 mmHg due to the majority of our patients

having NTG. Given that our study and the review used the same definition of success, the different success rates between our study and the review article is most likely accounted for by the difference in baseline IOP. This effect of lower percentage of IOP reduction due to lower baseline IOP was seen in a study on NTG by Lee *et al.*, where an IOP reduction of only 15% was reported with baseline IOP of 14.3 ± 3.4 mmHg.¹⁹ Nevertheless, even 1 mmHg of IOP reduction can reduce the risk of visual field progression by 10%.²⁰ Positive results have also been reported in the LiGHT study. They demonstrated that SLT provided better IOP control over the course of three years, with more follow-up meeting target IOP compared to eyedrops, less intense drop treatment, lower rates of disease deterioration, and no further glaucoma surgeries needed.²¹

From the IOP trend in the success group, we can observe that IOP post-treatment decreased significantly as early as one week and a significant reduction was seen again at six months. This suggests that, in this group of patients with mild to moderate disease, it is worthwhile to wait for at least six months to observe the full effect of SLT before deciding the next steps of management, provided that the patient has responded at the early stage.

Besides baseline IOP, our study also showed that SLT significantly reduced peak IOP and IOP fluctuations. Higher mean IOP peak and IOP fluctuations during the WDT were reported to be associated with visual field progression.¹⁷ Asrani *et al.* showed that large diurnal IOP fluctuations were an independent risk factor in glaucoma patients.²² Our results are in line with a study by Lee *et al.* demonstrating significant reduction in mean, peak, and range of IOP during the nocturnal period, following additional SLT in medically treated glaucoma patients.²³

Not all patients respond to SLT in the same manner. Our study attempted to identify the factors that might be able to predict likelihood of success, which can serve as a guideline in the management of glaucoma patients. In this study, SLT success was significantly predicted by MD on HVF and IOP one week post-treatment. Lower MD is indicative of greater disease severity. Gottanka *et al.* reported that increasing severity of POAG was accompanied by an increase in the amount of plaque material in the TM.²⁴ We postulate that SLT reduces TM resistance and improves the aqueous outflow, hence lowering IOP. This association has not been reported before in the literature. A study on Chinese patients looked at another HVF parameter, the visual field index (VFI), and reported no significant association.²⁵

We found that lower IOP at one week can predict SLT success at six months. The significance of lower IOP in the earlier phase as a predictor of SLT success was also in line with other two studies by Lee *et al.* They found that lower one-day IOP post-treatment in POAG patients²⁶ and one-week IOP post-treatment in NTG patients¹⁹ were both significant predictors for success. It was postulated that greater IOP reduction at an early phase may represent a higher level of metalloproteinase, cytokines, and macrophages, which have been proposed to be the biological agents responsible for IOP lowering.²⁷

Many studies have reported that baseline IOP is a consistent and strong predictor of SLT success.^{18,19,28} Our study failed to demonstrate this association significantly, although the success group did have a higher mean IOP compared to the non-success group. The reason for this might be due to lower baseline IOP in our study (as NTG made up of 50% of total cases) and small sample size. Similarly, Gracner *et al.* did not find a significant correlation between baseline IOP and success.²⁹ The baseline IOP in their study was 22.5 mmHg, which was lower compared to other similar studies. Lower baseline IOP has been associated with reduced pressure-lowering effect.³⁰

The side effects of SLT are minor. A transient IOP spike is common. A short increase of more than 5 mmHg above baseline IOP was recorded in 4.5-27.0% of patients.³¹⁻³² Our study documented a 4.2 ± 3.4 mmHg increase one hour post-SLT, which dropped below baseline IOP at one week. More severe side effects like corneal or macular oedema, peripheral anterior synechiae, hyphaema, severe uveitis, or persistent IOP rise were very rare and they were not seen in our study.

The main limitation of this study is its small sample size. Secondly, the patient population in this study included only mild and moderate disease. Therefore, the results of this study cannot be extrapolated to patients with severe and advanced disease. We selected this group of patients because it guaranteed that there would be no changes in treatment throughout the six-month study period. This may not be feasible in patients with severe and advanced disease. Thirdly, 50% of the patients in our study belonged to the NTG group, which provided a lower baseline IOP compared to other studies that mainly consist of POAG and OHT patients. Thus, the findings of this study might not reflect the true results of the POAG and OHT groups.

In conclusion, this study showed that SLT can be used to treat mild to moderate POAG, NTG, and OHT patients, whether as first-line treatment or as an adjunct to medical therapy before more invasive surgeries are considered. The success rate at six months was 44%. The significant predictors of success were MD on HVF and IOP one week post-treatment. In the future, further research is needed to demonstrate the repeatability of the procedure to maintain IOP under control.

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