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Ophthalmology Section

Anterior Segment Optical Coherence Tomography in Evaluation of Impact of Laser Peripheral Iridotomy on Anterior Segment Morphology and IOP in Primary Angle Closure Spectrum Patients: A Quasi-experimental Study

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ABSTRACT

Introduction: A leading cause of bilateral blindness worldwide, Primary Angle Closure Glaucoma (PACG) is estimated to affect 16 to 20 million people, with an estimated four million bilaterally blind. Laser Peripheral Iridotomy (LPI) is the primary treatment for angle closure based on its ability to relieve pupillary block. After LPI in eyes with narrow angles, progression to angle-closure glaucoma is uncommon, even in high-risk eyes such as the fellow eyes of patients with a unilateral acute angle-closure attack. Gonioscopy is limited in its ability to accurately characterise Anterior Chamber (AC) morphology. Anterior Segment Optical Coherence Tomography (AS-OCT), however, has emerged as a method for obtaining objective, reproducible high-resolution images that allow for quantification of AC parameters.

Aim: The present study was aimed to evaluate, by AS-OCT, the changes in the AC angle width parameters following N:d YAG LPI in patients with Primary Angle Closure (PAC) spectrum patients and to study the Intraocular Pressure (IOP) changes following N:d YAG LPI in patients with PAC Spectrum (PACS) patients.

Materials and Methods: The present quasi-experimental study was done in the Ophthalmology Department at SRM Medical College Hospital and Research Centre, Katthankulathur, Chennai, Tamil Nadu, India. Forty eyes were included in the study, this includes Best-Corrected Snellen Visual Acuity (BCVA), Slit-lamp evaluation including Van Herick's Grading of angle and Lens status, Goldmann Applanation Tonometry, Corneal Pachymetry (CCT), undilated fundoscopy, gonioscopy and anterior segment OCT were performed at baseline. Tonometry and gonioscopy were performed on first week follow-up visit. While repeat AS-OCT was performed at one month follow-up visit. Changes in mean values between baseline (Pre LPI) and post LPI visits were assessed using statistical methods such as paired student's t-test and Chi-square test. The p-value less than 0.05 were considered statistically significant.

Results: The mean IOP prior to LPI was 22.33 mmHg, which reduced to 16.95 mmHg Following LPI ($p<0.001$). Mean CCT was 536.675 um, with minimum being 500 um and maximum being 560 um. AC angle parameters on AS-OCT, i.e.,- Trabecular-Iris Angle (TIA), AOD 500, AOD 750, TISA 500, TISA 750, Scleral Spur Angle (SSA), Anterior Chamber Width (ACW) and Anterior Chamber Area (ACA), all increased significantly following LPI ($p<0.001$ for all parameters). Thus, demonstrating widening of AC angle and flattening of the convex Iris configuration following LPI. Central AC depth had insignificant but minimal change following LPI ($p>0.05$)

Conclusion: LPI is efficacious in widening of the AC angle in eyes with PACS disease in the short term. AS-OCT as an imaging modality has several advantages that make it an excellent tool for large-scale screening of PACG.

Keywords: Glaucoma, Gonioscopy,Intraocular pressure, Narrow angle eyes

INTRODUCTION

Population-based studies showed that the prevalence of angle-closure glaucoma in South India ranges from 0.5 to 2.75% [1], which reported a greater prevalence of PACS when compared to that of PAC or PACG [2-6].

The LPI is the initial treatment for angle closure as it can potentially alleviate pupillary block. Post-LPI in the patients who has narrow angle, advancement to angle-closure glaucoma is not common, also in higher risk eyes like other eyes of the patients with unilateral acute angle closure attack. There was remarkable increase in all the average parameters of angle post-LPI (TISA500, TISA750, TICV500, and TICV750) [7]. Most common initial treatment for Primary Angle Closure Disease (PACD) is LPI [8]. LPI will widen the iridocorneal angle and will flatten iris circumferentially in Caucasian eyes [9]. But LPI does not always prevent progression of angle-closure and some patients who undergo LPI later on may develop increased Intraocular Pressure (IOP) [10,11], Peripheral Anterior Synechiae (PAS) [12], or glaucomatous visual damage [10]. Persistent Irido-trabecular Contact (ITC) is seen in about 20% of eyes after LPI, which partly explains the progression to angle-closure [13-15].

Gonioscopy is limited in its ability to accurately characterise LPI-induced changes in AC morphology. AS-OCT, however, has emerged as a method for obtaining objective, reproducible high-resolution images that allow for quantification of AC parameters [16]. ASOCT is a non-contact optical system which can be performed under standardised dark conditions, and can be operated with minimal expertise. Hence, it may have potential for use as an imaging tool to detect eyes with angle closure and monitor the effectiveness of laser treatment such as prophylactic LPI [17].

The LPI results in a significant increase in the angle width in PACS [18]. Gonioscopic assessment is subjective and can be difficult to perform in a reproducible fashion, which may limit its potential as a reference standard [19] whereas, ASOCT provides high resolution images to assess AC parameters.

While gonioscopy is only limited in characterising LPI-induced changes in AC morphology accurately, ASOCT became a procedure to obtain objective and high-resolution images which allows measurement of the AC parameters. One quick, non-contact way to image angle structures is with ASOCT. In comparison to gonioscopy, it is extremely sensitive in identifying angle closure. Compared to gonioscopy, more people had closed angles with AS-OCT [20].

One of the most common reasons to use gonioscopy is to examine the iridocorneal angle for angle closure. Although gonioscopy is very quick and easy to use, it does not offer a straightforward way to precisely records the degree of angle opening. Based only on gonioscopy, there are no precise guidelines for determining if a patient needs a laser iridotomy for angle closure. A recent study found that when an algorithm based on pre-treatment AS-OCT scans was applied the AS-OCT parameters performed better than glaucoma-trained ophthalmologists in predicting the success of LPI for PACS eyes [21]. ASOCT can be used to evaluate mechanism of angle closure like pupillary block and anterior lens vault based on iris profile and the lens location with respect to the anterior segment structures. This study is aimed to evaluate, by AS-OCT, the changes in the AC Angle width parameters following N:d YAG LPI in patients with PACS Patients and to study the IOP Changes following N:d YAG LPI in patients with PACS Patients.

MATERIALS AND METHODS

The present quasi-experimental study was conducted in the Department of Ophthalmology at SRM Medical College, Hospital and Research Centre, Chennai, Tamil Nadu, India. over a duration of 1.5 years. This study included 40 eyes from patients who presented with shallow AC and met the inclusion criteria for PACS. The duration of this study is 1.5 years with a sample size of 40 eyes and the method used is purposive sampling. The study was approved by the Institutional Ethics Committee of SRM Medical College (Approval No: 1600/IEC/2019) and informed consent was obtained from all participants prior to inclusion in the study.

Inclusion and Exclusion criteria: Inclusion criteria comprises of patients with need of PACS aged more than 40 years and subjects with grade 2 (Narrow angle with visible trabecular meshwork) or less as per modified Shaffer's grading of AC angle were included. Whereas, the Exclusion criteria was specific to patients with POAG, any other types of secondary angle closure glaucoma, previous intraocular surgery, congenital glaucoma, any previous laser procedure performed, those with remarkable retinal disease, any previous trauma history to eyes and ocular surface disorders including ptergium/corneal opacity were excluded.

According to the clinical findings, PAC were categorised into "PAC Suspects", "PAC" and "PACG ".

Study Procedure

A comprehensive ophthalmic examination was conducted with all the patients to assess structural and functional aspects of the eye. Best Corrected Visual Acuity (BCVA) was assessed using Snellen's chart. Slit-lamp biomicroscopy was executed to evaluate anterior segment, which included Van Herick's grading for Anterior Chamber Depth (ACD) and documentation of the lens status. Undilated fundus examination was carried out to examine posterior segment structures without pharmacological pupil dilation. Gonioscopy was conducted using goniolens to calculate AC angle, and angle grading was documented.

The IOP was measured using Goldmann Applanation Tonometry, and Central Corneal Thickness (CCT) was documented using a pachymeter. Visual field testing was implemented with Humphrey Field analyser to identify any glaucomatous or non-glaucomatous visual field defects. AS-OCT was utilised to find quantitative measurements of the AC angle. The AS-OCT parameters were calculated in both the nasal and temporal quadrants and incorporated TIA, angle opening distance at 500 µm and 750 µm from the scleral spur (AOD500 and AOD750), trabecular-iris space area at the same distances (TISA500 and TISA750), SSA, ACD, ACW, and ACA. These findings were documented and compared with gonioscopic angle grading to analyse their correlation. All clinical and imaging data were methodically recorded in a standardised proforma for all patients.

The LPI was performed using an ophthalmic neodymium-doped yttrium-aluminum-garnet (Nd:YAG) laser with the help of Abraham iridotomy contact lens. The procedure was carried out at the superior periphery of the iris, typically between the 10 and 2 o'clock positions. Full-thickness perforation of the iris was confirmed by observing a pigment surge and the flow of aqueous humour from posterior chamber into AC. After the procedure, patients were prescribed topical prednisolone acetate 1.0% for one week to control inflammation, along with IOP-lowering eye drops such as brimonidine, apraclonidine, or timolol to prevent post laser rise in IOP. The timing of LPI procedure was kept as early as possible to avoid potential loss of follow-up due to any negligence by the patients.

STATISTICAL ANALYSIS

For statistical analysis, data was documented in MS Excel and appropriate analysis was done using Statistical Package for Social Sciences (SPSS) latest software. Changes of mean values in Pre and post-LPI visits were evaluated by appropriate statistical methods such as paired student's t-test and Chi-square test. The p-value less than 0.05 was considered statistically significant.

RESULTS

Total of 40 eyes which underwent LPI were considered in this study. Mean age was 59.95 years, with majority in 56-60-year-old age group. Females (60%) were more than males (40%) in my study [Table/Fig-1]. A 45% of patients had PACS, 37.5% had PAC and 17.5% had PACG [Table/Fig-2]. Majority (30%) of the eyes were having Van Herick's Grade 2 prior to LPI, which changed to Van Hericks's Grade 3 following LPI [Table/Fig-3]. Majority (40%) of the eyes were having modified Shaffer's Grade 1 prior to LPI, which changed to modified Shaffer's Grade 3 post-LPI [Table/Fig-4].

Gender	Frequency	Percentage (%)
Male	8	40.0
Female	12	60.0

[Table/Fig-1]: Demographic data of the study population (n=40)

Frequency distribution	PACS	PAC	PACG
Frequency	18	15	7
Percentage(%)	45.0	37.5	17.5

[Table/Fig-2]: Frequency distribution of PACS, PAC, PACG (n=40).
PACS: Primary angle closure suspect; PAC: Primary angle closure; PACG: Primary angle closure glaucoma

Van Herick's Grading -Pre Laser		Van Herick's Grading-Post Laser			
		Grade 2	Grade 3	Grade 4	Total
Grade 1	Count	8	9	4	21
	% of Total	20.0%	22.5%	10%	52.5%
Grade 2	Count	3	16	1	20
	% of Total	5.0%	30.0%	10%	45%
Grade 3	Count	1	10	4	15
	% of Total	0.00%	2.50%	0.00%	2.5%

Total	Count	5	28	7	40
	% of Total	25.0%	55.0%	20.0%	100%

[Table/Fig-3]: Changes in Van Herick's Grading of angle (n=40).
LPI: Laser peripheral iridotomy

Gonioscopy Grading - modifies Shaffer's grading pre laser		Gonioscopy Grading - modified Shaffer's grading -Post laser			
		Grade 2	Grade 3	Grade 4	Total
Grade 0	Count	1	0	0	1
	% of Total	2.5%	0%	0%	2.5%
Grade-1	Count	3	16	1	20
	% of Total	7.50%	40.0%	2.50%	50.0%
Grade-2	Count	1	10	4	15
	% of Total	2.50%	25.0%	10.0%	37.5%
Grade-3	Count	0	2	2	4
	% of Total	0%	5%	5%	10%
Total	% of tota	25.0%	55.0%	20.0%	100%

[Table/Fig-4]: Changes in Modified Shaffer's Gonioscopic Grading of Angle (n=40).
LPI: Laser peripheral iridotomy

A total of 12 eyes (30%) had Peripheral Anterior Synechiae (PAS), while remaining 28 eyes (70%) had no PAS [Table/Fig-5].

Frequency of PAS	Frequency	Percentage (%)
PAS	12	30
No PAS	28	70

[Table/Fig-5]: Frequency of PAS (n=40).
PAS: Peripheral anterior synechiae

Mean CCT was 536.675 um, with minimum being 500 um and maximum being 560 um.

Mean IOP prior to LPI was 22.33 mmHg, which reduced to 16.95 mmHg following LPI. Mean true IOP prior to LPI was 22.73 mmHg, which reduced to 17.38 mmHg Following LPI. True IOP is the corrected IOP according to CCT.

Mean TIA in nasal quadrant prior to LPI was 19.08°, which increased to 26.83° post LPI, Mean TIA in temporal quadrant prior to LPI was 19.28°, which increased to 27.03° post LPI. Overall average TIA prior to LPI was 19.175° which increased to 26.925° following LPI. Increase in TIA Following LPI was significant (p<0.001).

Angle Opening Distance 500: Mean AOD 500 in Nasal Quadrant prior to LPI was 0.3002 mm, which increased to 0.4468 mm post LPI. Mean AOD 500 in temporal quadrant prior to LPI was 0.297 mm, which increased to 0.4313 mm post-LPI. Overall average AOD 500 prior to LPI was 0.2986 mm which increased to 0.439 mm following LPI. Increase in AOD 500 following LPI was significant (p<0.001) [Table/Fig-6].

Parameters	Nasal	Temporal	Overall	p-value
Pre laser	0.3002	0.297	0.2986	0.001
Post laser	0.4468	0.4313	0.439	0.001

[Table/Fig-6]: Angle opening distance 500 mm.
Mean AOD 500 mm; p-value <0.005 is statistically significant; AOD: Angle opening distance; LPI: Laser pripheral iridotomy

Angle opening distance 750: Mean AOD 750 in nasal quadrant prior to LPI was 0.4018 mm, which increased to 0.5480 mm post LPI. Mean AOD 750 in temporal quadrant prior to LPI was 0.297 mm, which increased to 0.4313 mm post LPI. Overall average AOD 750 prior to LPI was 0.2986 mm which increased to 0.439 mm following LPI. Increase in AOD 750 following LPI was significant (p<0.001) [Table/Fig-7].

Trabecular - IRIS Space Area 500: Mean TISA 500 in nasal quadrant prior to LPI was 0.1037 mm^2, which increased to 0.1520 mm^2 post LPI. Mean TISA 500 in temporal quadrant prior to LPI was 0.1057 mm^2, which increased to 0.1465 mm^2 post LPI. Overall

Parameters	Nasal	Temporal	Overall	p-value
Pre-laser	0.4018	0.297	0.2986	0.001
Post laser	0.5480	0.4313	0.439	0.001

[Table/Fig-7]: Mean AOD 750 mm values.
Mean AOD 750 mm; p-value <0.05 is statistically significant; AOD: Angle opening distance; LPI: Laser peripheral iridotomy

Average TISA 500 prior to LPI was 0.1048 mm^2 which increased to 0.1493 mm^2 following LPI. Increase in TISA 500 Following LPI was significant (p<0.001) [Table/Fig-8].

Parameters	Nasal	Temporal	Overall	p-value
Pre-laser	0.1037	0.1057	0.1048	0.001
Post laser	0.1520	0.1465	0.1493	0.001

[Table/Fig-8]: Mean TISA 500 (mm^2).
Mean TISA 500 (mm^2); p-value <0.05 is statistically significant; TISA: Trabecular-iris space area

Trabecular - Iris Space Area 750: Mean TISA 750 in Nasal Quadrant prior to LPI was 0.2017 mm^2, which increased to 0.28925 mm^2 post LPI. Mean TISA 750 in temporal quadrant prior to LPI was 0.2013 mm^2, which increased to 0.28775 mm^2 post-LPI. Overall Average TISA 750 prior to LPI was 0.2015 mm^2 which increased to 0.2885 mm^2 following LPI. Increase in TISA 750 following LPI was significant (p<0.001) [Table/Fig-9].

Parameters	Nasal	Temporal	Overall	p-value
Pre-Laser	0.2017	0.2013	0.2015	0.001
Post laser	0.28925	0.28775	0.2885	0.001

[Table/Fig-9]: Mean TISA 750 (mm^2) value.
Mean TISA 750 (mm^2); p-value <0.05 is statistically significant; TISA: Trabecular iris space area

Scleral Spur Angle (SSA): Mean SSA in nasal quadrant prior to LPI was 31.48°, which increased to 40.60° post LPI. Mean SSA in temporal quadrant prior to LPI was 32.00°, which increased to 40.80° post LPI. Overall average SSA prior to LPI was 31.74° which increased to 40.7° following LPI. Increase in SSA following LPI was significant (p<0.001).

Anterior Chamber Depth (ACD): Central AC Depth prior to LPI was 2.2558 mm, which increased to 2.2620 mm post LPI. The increase in AC Depth was insignificant as p-Value > 0.05 (p=0.247).

Anterior Chamber Width (ACW): The AC Width prior to LPI was 10.76 mm, which increased to 11.28 mm post LPI. The increase in AC width was significant (p<0.001).

Anterior Chamber Area (ACA): The ACA prior to LPI was 15.83 mm^2, which increased to 17.32 mm^2 post LPI. [Table/Fig-10] The increase in ACA was significant (p<0.001).

Parameters	Pre Laser	Post Laser	p-value
Mean IOP	22.325	16.95	0.001
Mean True IOP	22.725	17.375	0.001
Mean CCT	536.675	536.675	0.313
Mean TIA	19.175	26.925	0.001
Mean AOD 500	0.299	0.439	0.001
Mean AOD 750	0.402	0.557	0.001
Mean TISA 500	0.105	0.149	0.001
Mean TISA 750	0.202	0.289	0.001
Mean Scleral Spur Angle (SSA)	31.738	40.7	0.001
Mean AC Depth	2.256	2.262	0.247
Mean AC Width	10.76	11.28	0.001
Mean Anterior chamber Area (ACA)	15.83	17.32	O.001

[Table/Fig-10]: Final results.

Follow-up

Patients were asked to visit for follow up after one week (to evaluate for early post laser inflammation and IOP) and one month

(±7 days) (to evaluate for PI patency, if failed iridotomy, IOP) post LPI. Repeat slit lamp examination, IOP and Gonioscopy were performed on first week follow-up visit. While repeat AS-OCT was performed at one month follow-up visit. Visual fields were performed on either of the follow up visits (one week post LPI or one month Post-LPI) which help to distinguish between PAC and PACG.

DISCUSSION

The present study was aimed to assess the changes in AC parameters following LPI in patients with PACS, PAC, and PACG, using AS-OCT and gonioscopy. The results demonstrated a statistically significant increase in all the peripheral AC parameters which includes AOD 500, AOD 750, TISA 500, TISA 750, SSA, ACW, and ACA and central AC depth showed a minimal or no significant change.

Pupillary block is the main cause of narrow AC angle. In this condition, there is resistance outflow of aqueous humour outflow at pupillary border, creating pressure gradient between anterior and posterior chambers. Pressure buildup causes iris to bow forward and narrowing the AC angle. The iris convexity suggests pupillary block, and degree of bowing indicates extent of the block, which is crucial in determining the width of AC angle. LPI is treatment procedure which will create opening in peripheral iris using laser, which will allow aqueous humour flow straight into AC. This bypasses pupillary block and equalises pressure in anterior and posterior chambers, causing iris to flatten and move away from angle. Degree of angle widening post LPI will depend up on reduction in forward bowing of the iris. When pupillary block is only cause of angle closure, LPI will flatten iris by eliminating pressure difference. If the iris is fully flattened post LPI, quantity of pupillary block before the procedure determines the extent of the iris posterior shift afterward.

A narrow angle prior to LPI, because of high degree of pupillary block, should reveal comparatively wide opening of the AC angle post LPI because of greater posterior iris displacement. The Liwan eye Study also showed that narrower AC angle observed in ultrasound biomicroscopy before LPI experienced most significant widening of the AC angle after the procedure. It is observed to present predominantly in older age groups. In this study, the average age was 59.95 years, with majority in 56-60-year age group. A probable reason for this prevalence in older ages is the delayed detection and late presentation of such patients for ophthalmological evaluation. Early identification of PACG is crucial, as it allows for the timely management and reducing disease progression and ensuring good vision throughout life.

Zebardast N et al., (2016) study reported a higher prevalence of PACG in females, with 78% of PACS patients and 67% of PAC/PACG patients being female [16]. It was consistent with this study, where females (60%) outnumbered males (40%). In this current study, angle parameters showed significant increases in AOD 500 (0.298 mm vs 0.439 mm, p<0.001), AOD 750 (0.402 mm vs 0.55675 mm, p<0.001), TISA 500(0.10475 mm^2 vs 0.14925 mm^2, p<0.001), TISA 750 (0.2015 mm^2 vs 0.2885 mm^2, p<0.001), SSA (31.7375 vs 40.7, p<0.001), ACW (10.76 mm vs 11.28 mm, p<0.001), and ACA (15.83 mm^2 vs 17.32 mm^2, p<0.001), while only ACD (2.25575 vs 2.262, p=0.247) showed minimal or no significant change. The results in this study correlate with previous studies indicates that peripheral AC broadens post LPI, as evidenced by remarkable raise in TIA, AOD 750, and TISA 750 on AS-OCT, with minimal change in ACD.

This study showed that mean AOD 500 increased from 0.299 mm to 0.439 mm, and mean TISA 750 increased from 0.202 mm^2 to 0.289 mm^2 (p<0.001). These findings are comparable to Zebardast N et al., (2016) demonstrated AC angle widening on AS-OCT with significant increase in AOD 750 (0.201 mm vs 0.226 mm, p<0.001), ARA 750 (0.068 mm^2 vs 0.076 mm^2, p<0.001), TISA 750 (0.068 mm^2 vs 0.076 mm^2, p<0.001), ACW (10.24 mm vs 11.36 mm, p<0.001), and ACA (14.96 mm^2 vs 15.70 mm^2; p<0.001), with minimal change in ACD (2.11 mm vs 2.12 mm, p=0.04) [16].

Koh V et al., (2019) found that AS-OCT showed a slight decrease in AOD 500 (0.44 mm vs. 0.40 mm, p=0.59) following LPI, while other parameters showed significant increases: AOD 750 (0.48 mm vs. 0.58 mm, p=0.024), angle recess area 750 (0.23 mm^2 vs 0.27 mm^2, p=0.032), TISA 750 (0.21 mm^2 vs. 0.29 mm^2; p<0.001), ACA (17.17 mm^2 vs. 19.78 mm^2; p=0.055), and ACD (1.99 mm vs. 2.13 mm, p=0.018) [17]. How AC et al., (2012) found that the mean angle width (modified Shaffer grade) increased from 0.68 ÷ 0.59 at beginning to 1.76 ÷ 0.69 post LPI (p <0.001), with parallel increases in AOD 500 (0.12 mm vs. 0.19 mm, p<0.001), TISA 500 (0.06 mm^2 vs. 0.08 mm^2 p<0.001), angle recess area (0.13 mm^2 vs. 0.17 mm^2, p<0.001), as well as ACA (15.00 mm^2 vs. 16.00 mm^2 p<0.001). The increase in ACW was insignificant (11.21 mm vs.11.24 mm, p=0.3) [18]. The obtained results indicate that AC angle widens following LPI. This suggests that narrowest AC angle at the beginning is showed greater widening of AC angle post LPI. In contrast, Lee RY et al. demonstrated an inverse relationship, where more crowded AC angles at beginning showed greater widening after LPI [19].

The present study highlights on how the AC angle significantly widens post-LPI, especially in eyes where the angle was narrow before the procedure. These results lend reliance to LPI's efficacy as a first line of treatment for PACS patients. These findings also highlight the value of AS-OCT as an excellent objective and non-invasive method for assessing angle configuration and tracking treatment results.

Limitation(s)

This study proved that LPI significantly widens AC angle in patients with PACS in South Indian population, as measured by AS-OCT. However, some eyes continued to show ITC on gonioscopy, especially in cases with more advanced angle closure such as PAC or PACG. LPI proved to be effective in short-term management of angle closure, but long-term follow-up is needed to evaluate its role in preventing glaucoma progression.

AS-OCT offers objective and detailed imaging, making it a valuable tool for screening and evaluating narrow angles. While gonioscopy remains necessary, AS-OCT should be widely used in tertiary centers for early detection of PACG.

CONCLUSION(S)

AS-OCT is a magnificent objective method to assess the angle changes and for guidance in early management (like LPI). Early detection of angle closure with the help of AS-OCT and planning LPI in patients will to prevent progression of glaucoma.

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