· **Clinical Research** ·

# Evaluation of the learning curve of laser peripheral iridectomy: the 20th case reaches the turning point

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## Abstract

● **AIM:** To explore the learning curve for ophthalmologists at the start of laser peripheral iridectomy (LPI) training.

● **METHODS:** The learning curve of 4 doctor groups without previous LPI experience was studied. Three main parameters of LPI were reviewed: total energy, argon energy and neodymium-doped yttrium aluminum garnet (Nd:YAG) energy. Procedures were evaluated in cohorts of 20 cases to identify the turning points of the three variables.

● **RESULTS:** There was no significant difference in terms of age or eye among the 4 doctor groups. There were stable trends on the learning curve for the Doctor A and C groups regarding total energy and argon energy. In addition, the turning points on the learning curve were determined after the 20th procedure for the Doctor B and D groups regarding total energy and argon energy. Moreover, the Nd:YAG energy was relatively stable since the first procedure.

● **CONCLUSION:** It requires approximately 20 procedures for a beginner to reach a turning point on the learning curve regarding LPI. It can serve as a point of reference or guideline for training beginners to perform LPI.

● **KEYWORDS:** learning curve; laser peripheral iridectomy; primary angle-closure glaucoma

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## INTRODUCTION

According to a recent Meta-analysis, the incidence of primary angle-closure glaucoma (PACG) in China is 0.7%, which is higher than the overall total prevalence of PACG (0.6%) worldwide[1]. Patients with primary angle-closure suspect (PACS) accounted for approximately 4.68%[2]; 3.09% of patients with PACS developed primary angle closure (PAC) and PACG[3]. By 2050, the total number of glaucoma cases in China will reach 25.16 million[4], which will definitely become a major burden on the health system.

Laser peripheral iridectomy (LPI) is one of the treatment options for angle closure because it can establish an outflow channel of aqueous humor and alleviate pupillary block[5-6]. After LPI, the iris becomes flat, and the angle of the chamber widens[7-10]. LPI is indispensable for glaucoma treatment[11-12].

It was reported that the rate of repeat procedures (RPs) for LPI was related to the operating surgeon's level of experience[13]. However, the parameters of LPI were not included in the study to explore how the level of experience contributed to the rate of RPs. Kam *et al*[14] demonstrated that the total power used for LPI decreased as the length of resident training increased by comparing individual years of training. Although the study covered the parameters used for LPI, grouping exclusively by individual years of training resulted in too long a time span to present a more accurate learning curve. Therefore, the precise learning curve based on cohorts of cases in a large sample remains elusive.

In this study, a retrospective study was implemented to investigate the learning curve based on a cohort of doctor groups cases in a large sample of LPI procedures by comparing the three main parameters of LPI for four doctor groups since they learned to perform LPI.

## SUBJECTS AND METHODS

**Ethical Approval**  This trial was approved by the Ethics Committee of Sun Yat-sen University and Zhongshan

**Table 1 Clinical characteristics of patients with LPI**

| Characteristics | Total number of patients ($n$=395) | Doctor A ($n$=100) | Doctor B ($n$=95) | Doctor C ($n$=100) | Doctor D ($n$=100) | [c]$P$ |
|---|---|---|---|---|---|---|
| Age[a] | 61.530±36.445 | 58.930±11.094 | 67.830±72.050 | 59.310±9.776 | 60.380±9.334 | 0.282 |
| Gender[b] | | | | | | 0.033 |
| Male | 102 | 32 | 26 | 29 | 15 | |
| Female | 293 | 68 | 69 | 71 | 85 | |
| Eye of LPI[b] | | | | | | 0.713 |
| Right | 193 | 53 | 43 | 50 | 47 | |
| Left | 202 | 47 | 52 | 50 | 53 | |

LPI: Laser peripheral iridectomy; [a]Student's $t$ test was used; [b]Chi-square test was used. [c]$P$<0.05 represented statistical significance.

Ophthalmic Center and the protocol ID was 2019KYPJ182. This experiment was conducted in accordance with the principles of the Declaration of Helsinki.

**Experimental Design and Participants**　All inspections and interventions were performed in Zhongshan Ophthalmic Center, a tertiary first-class hospital in Guangzhou, China.

Patients who were diagnosed with PACS/PAC and treated with LPI in Zhongshan Ophthalmic Center from July 2017 to October 2019 were included in the study.

Inclusion criteria: 1) Patients with PACS and patients with PAC; 2) No glaucomatous optic neuropathy observed in the fundus examination.

Exclusion criteria: 1) The presence of serious systemic health problems; 2) Previously performed internal eye surgery; 3) The refractive medium was turbid, and LPI could not be performed; 4) The best-corrected visual acuity was less than 20/40.

**Laser Peripheral Iridectomy**　One drop of brimonidine 0.15% (Allergan, Irvine, CA, USA) and pilocarpine 2% (Pharmacy of Zhongshan Ophthalmic Center, Guangzhou, China) were dripped in the intervention eye 15min separately before procedure. They were able to decline IOP spikes and to thin the peripheral iris so that less laser energy would be needed for having the iris penetrated. Patients were treated in the peripheral super-nasal or super-temporal region (within the range from 10 to 2 o'clock) and preferably chosen specific whereas iris appeared thinnest such as a crypt. The argon laser (Carl Zeiss Meditec, Inc.) and neodymium-doped yttrium aluminum garnet (Nd:YAG, Visulas YAG III; Carl Zeiss Meditec, Dublin, CA, USA) laser were sequentially applied. First, the argon laser was used to produce a crater to shrinkage the whole iris thickness. Then the iris was penetrated with Nd:YAG laser. LPI perforation was recognized when the posterior aqueous humor flowed into the anterior chamber and the iris loss pigment at the peripheral incision hole. After LPI, Tobramycin and Dexamethasone eye drops and at least one drug that reduces eye pressure was administered. All patients used Tobramycin and Dexamethasone eye drops 6 times a day for one week after LPI. The laser parameters used in the procedure, including the aperture size, number of points, energy of the argon laser and the Nd:YAG laser, were recorded.

**Statistical Analysis**　Statistical analysis was performed using SPSS software (IBM SPSS Statistics 23.0) and GraphPad Prism (8.0.1.244). Data with normally distributed data are reported as the mean±standard deviation (SD). Student's $t$ test and the Chi-square test were used to compare the differences in baseline data and LPI parameters. The scatter plot is used to evaluate the trend of the LPI parameter as the beginner performs more procedures. According to the distribution trend of the scatter plot, every 20th procedure was divided into a group to identify the turning point on the learning curve. In addition, the test level ($\alpha$) was 0.05.

**RESULTS**

**Demographics and Clinical Characteristics**　According to inclusion and exclusion criteria, a total of 395 patients was retrospectively involved into the study. Table 1 lists the baseline demographic and clinical data. The ages of the patients in the groups Doctor A, Doctor B, Doctor C, and Doctor D were 58.930±11.094y, 67.830±72.050y, 59.310±9.776y, and 60.380±9.334y, respectively ($P$=0.282). The detailed clinical data for all patients participating in the study are listed in Table 1.

**Doctors' Laser Peripheral Iridectomy Parameters**　The total energy, argon energy and Nd:YAG energy of Doctor A was 8.483±2.939, 7.933±2.807, and 0.500±0.381 J. The total energy, argon energy and Nd:YAG energy of Doctor B was 6.697±1.854, 6.143±1.798, and 0.551±0.326 J. The total energy, argon energy and Nd:YAG energy of Doctor C was 5.982±1.738, 5.399±1.625, and 0.570±0.300 J. The total energy, argon energy and Nd:YAG energy of Doctor D was 4.872±1.564, 4.444±1.577, and 0.399±0.248 J. More details can be viewed in Table 2.

**Doctors' Learning Curve Regarding the Laser Peripheral Iridectomy Parameters**　According to order, every 20th procedure was divided into a group. For total energy, there were significant differences between the first group and the second group ($P$=0.004, 0.030, 0.040, $P$<0.001, respectively). This difference decreases as the number of doctors' operations increases; in other words, the parameters appear to stabilize. More details can be viewed in Figure 1.
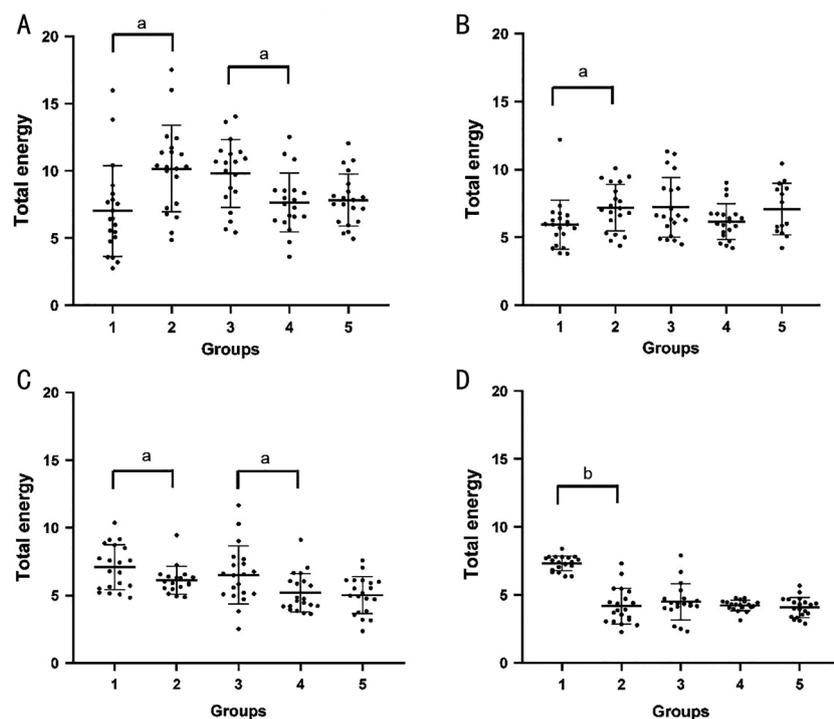
**Figure 1 The differences in total energy among Doctor A, B, C, and D groups** Every 20th procedure was divided into a group. [a]$P<0.05$, [b]$P<0.001$.

**Table 2 The doctors' LPI parameters**

| Doctor | Number | Total energy (J) | Argon energy (J) | No. of argon energy | Nd:YAG energy (J) | No. of Nd:YAG energy |
|---|---|---|---|---|---|---|
| A | 100 | 8.483±2.939 | 7.933±2.807 | 169.840±53.721 | 0.500±0.381 | 112.240±59.489 |
| B | 95 | 6.697±1.854 | 6.143±1.798 | 144.890±42.037 | 0.551±0.326 | 121.420±66.474 |
| C | 100 | 5.982±1.738 | 5.399±1.625 | 120.530±35.684 | 0.570±0.300 | 121.680±61.025 |
| D | 100 | 4.872±1.564 | 4.444±1.577 | 169.120±24.895 | 0.399±0.248 | 121.120±72.390 |

LPI: Laser peripheral iridectomy; Nd:YAG: Neodymium-doped yttrium aluminum garnet.

For argon energy, there were significant differences between the first group and the second group ($P=0.007$, 0.034, 0.035, $P<0.001$, respectively). Similarly, the parameters stabilized as the number of doctors' operations increased. More details were showed in Figure 2.

However, for Nd:YAG energy, the differences between the first group and the second group were not significant, except for Doctor A ($P=0.017$, 0.501, 0.627, 0.764, respectively). Interestingly, the Nd:YAG energy was stable from the first group to the fifth group in Doctor B. More details can be seen in Figure 3.

## DISCUSSION

To our knowledge, this is the first study reporting on the learning curve for LPI based on a large sample. Our research shows that the laser parameters stabilized after glaucoma doctors, who were beginners to performing LPI surgery, performed approximately 20 procedures. The Accreditation Council for Graduate Medical Education requires all ophthalmology residents to perform LPI before graduation. Riley et al[13] illustrated that the RP rate for LPI procedures was associated with the experience of the operating surgeon.

However, the reason why the level of experience contributed to the rate of RPs was not explained due to the lack of LPI parameters in this study. In addition, at the beginning of Nd:YAG application for LPI, Schwartz et al[15] speculated that LPI may involve a learning curve. At that time, the study paid more attention to assessing the safety and efficacy of LPI rather than placing focus on the learning curve associated with LPI. Our study proved that there was indeed a learning curve for LPI. Kam et al's[14] study showed that the total power used for LPI declined as resident training increased based on comparing individual years of training. The same result was observed in our study. However, in Kam et al's[14] study, the groups were established according to the individuals' years of training. The length of time was too extensive to implement an accurate learning curve. In conclusion, previous studies have shown that the LPI learning curve may exist. However, the precise learning curve based on cohorts of cases in a large number remains elusive. In this study, we investigated the learning curve based on LPI procedures by comparing the three main parameters of LPI for four doctor groups since they learned to perform LPI surgery, which definitely provides a
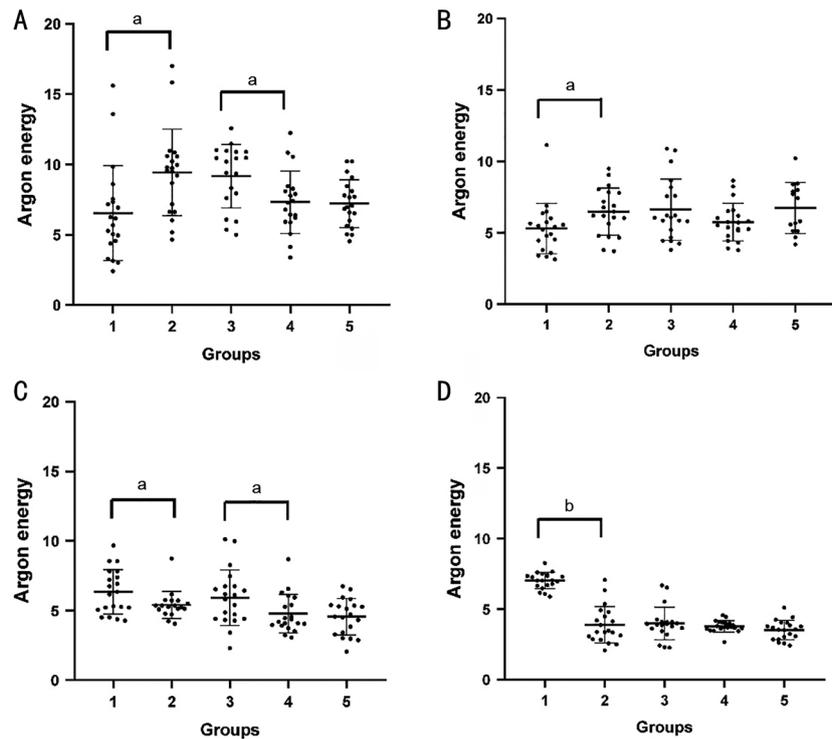
**Figure 2 The differences in argon energy among Doctor A, B, C, and D**  Every 20th case was divided into a group. $^{a}P<0.05$, $^{b}P<0.001$.
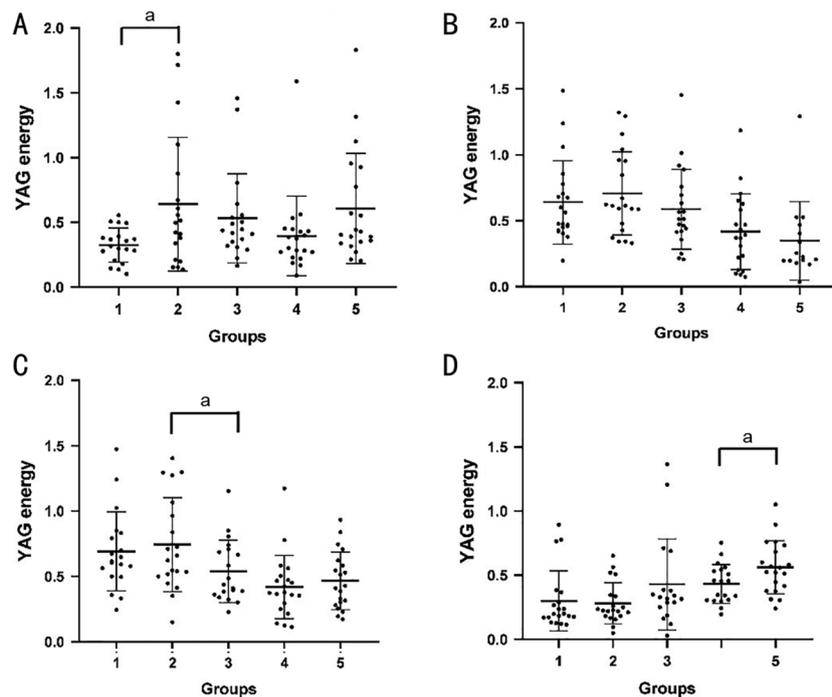


**Figure 3 The differences in Nd:YAG energy among Doctor A, B, C, and D**  Every 20th case was divided into a group. $^{a}P<0.05$. Nd:YAG: Neodymium-doped yttrium aluminum garnet.

more accurate depiction of the LPI learning curve.

The total energy was the sum of both argon energy and Nd:YAG energy. For total energy, there were significant turning points on the learning curve in the Doctor B and Doctor D groups (Figure 1). In addition, although the total energy still fluctuated to some extent in the other doctor groups, a centralizing tendency developed as the number of procedures increased. Similarly, Kam *et al*'s[14] study demonstrated that the total power used for LPI declined as the length of resident training increased. According to the results of previous studies, LPI that uses a large amount of total energy was a risk factor for postoperative peak intraocular pressure[16]. The total energy used for LPI decreased as the number of procedures increased, which was beneficial to reduce the peak postoperative

intraocular pressure and the occurrence of other complications. The argon energy also shows a significant turning point on the learning curve in the Doctor B and Doctor D groups (Figure 2). In contrast, the Nd:YAG energy seemed stable in the four doctor groups, especially in the Doctor B group (Figure 3). There seemed to be no turning point in Nd:YAG energy. The reason why the above results occurred may be due to the following reasons: the argon laser was mainly used to realize iris penetration, and iris perforation was achieved by the Nd:YAG laser[17]. Moreover, compared with Caucasians, previous studies[18-20] reported that the irises of Chinese Americans were thicker. Therefore, LPI beginners may prefer to use excessive argon energy to ensure penetration in the thick iris. Fortunately, they gradually master the appropriate amount argon energy needed to penetrate the iris as the number of procedures increase. However, with Nd:YAG energy as the second-stage laser, the energy needed was relatively certain. Therefore, it is easier for beginners to understand. Our study suggested that the LPI procedure requires experienced doctors to pay close attention to the use of argon energy during guided instruction.

LPI treatment in Chinese patients with thick irises was a major challenge[21]. Ho and Fan's[17] study illustrated that the protocol for LPI's sequential use of argon and Nd:YAG inherited most of the advantages of both laser types while avoiding some of their disadvantages, especially for dark irises. Ono et al's[22] longitudinal study demonstrated that the protocol for LPI's sequential use of argon and Nd:YAG lasers is effective and safe. In this study, the same strategy was applied.

The limitation of this study is that the included patients were Chinese and had thick irises. In addition, there might be some confounding bias because all data collected in the study was from a single medical institution.

In conclusion, our study demonstrated that a doctor should practice more than 20 LPIs to master the procedure. This requires more attention to the use of argon energy during guided instruction. This outcome can be applied to identify the appropriate length of training for doctors performing LPI.

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## REFERENCES

1 Zhang N, Wang JX, Chen BY, Li Y, Jiang B. Prevalence of primary angle closure glaucoma in the last 20 years: a meta-analysis and systematic review. *Front Med* (*Lausanne*) 2021;7:624179.

2 Qu W, Li Y, Song W, Zhou X, Kang Y, Yan L, Sui H, Yuan H. Prevalence and risk factors for angle-closure disease in a rural Northeast China population: a population-based survey in Bin County, Harbin. *Acta Ophthalmol* 2011;89(6):e515-e520.

3 He MG, Jiang YZ, Huang SS, Chang DS, Munoz B, Aung T, Foster PJ, Friedman DS. Laser peripheral iridotomy for the prevention of angle closure: a single-centre, randomised controlled trial. *Lancet* 2019;393(10181):1609-1618.

4 Song PG, Wang JW, Bucan K, Theodoratou E, Rudan I, Chan KY. National and subnational prevalence and burden of glaucoma in China: a systematic analysis. *J Glob Health* 2017;7(2):020705.

5 Radhakrishnan S, Chen PP, Junk AK, Nouri-Mahdavi K, Chen TC. Laser peripheral iridotomy in primary angle closure. *Ophthalmology* 2018;125(7):1110-1120.

6 Baskaran M, Kumar RS, Friedman DS, Lu QS, Wong HT, Chew PTK, Lavanya R, Narayanaswamy A, Perera SA, Foster PJ, Aung T. The Singapore asymptomatic narrow angles laser iridotomy study. *Ophthalmology* 2022;129(2):147-158.

7 Xu BY, Friedman DS, Foster PJ, Jiang Y, Pardeshi AA, Jiang YZ, Munoz B, Aung T, He MG. Anatomic changes and predictors of angle widening after laser peripheral iridotomy: the Zhongshan angle closure prevention trial. *Ophthalmology* 2021;128(8):1161-1168.

8 Gupta R, Kumar R, Chauhan L. Anterior chamber morphology changes in eyes with narrow angles by Scheimpflug imaging: Pilocarpine versus laser peripheral iridotomy. *Int Ophthalmol* 2021;41(6):2099-2108.

9 Zhekov I, Pardhan S, Bourne RR. Optical coherence tomography-measured changes over time in anterior chamber angle and diurnal intraocular pressure after laser iridotomy: impact study. *Clin Exp Ophthalmol* 2018;46(8):895-902.

10 Do T, Nguyen Xuan H, Dao Lam H, Tran Tien D, Nguyen Thi Thuy G, Nguyen Do Ngoc H, Verma S, Aung T. Ultrasound biomicroscopic diagnosis of angle-closure mechanisms in Vietnamese subjects with unilateral angle-closure glaucoma. *J Glaucoma* 2018;27(2):115-120.

11 Lusthaus J, Goldberg I. Current management of glaucoma. *Med J Aust* 2019;210(4):180-187.

12 Gao XB, Zhou YY, Zuo CG, Chen LM, Ren JW, Lin HS, Liao YR, Gong HJ, Hu HL, Lin MK. Predictive equation for angle opening distance at 750 μm after laser peripheral iridotomy in primary angle closure suspects. *Front Med* 2021;8:715747.

13 Riley OF, Mamtora S, Carroll E, Luck J. Surgical grade and repeat laser peripheral iridotomy procedures with risk stratification and educational considerations. *Clin Ophthalmol* 2020;14:4319-4323.

14 Kam JP, Zepeda EM, Ding L, Wen JC. Resident-performed laser peripheral iridotomy in primary angle closure, primary angle closure suspects, and primary angle closure glaucoma. *Clin Ophthalmol* 2017; 11:1871-1876.

15 Schwartz LW, Moster MR, Spaeth GL, Wilson RP, Poryzees E. Neodymium-YAG laser iridectomies in glaucoma associated with closed or occludable angles. *Am J Ophthalmol* 1986;102(1):41-44.

16 Jiang YZ, Chang DS, Foster PJ, He MG, Huang SS, Aung T, Friedman

DS. Immediate changes in intraocular pressure after laser peripheral iridotomy in primary angle-closure suspects. *Ophthalmology* 2012; 119(2):283-288.

17 Ho T, Fan R. Sequential argon-YAG laser iridotomies in dark irides. *Br J Ophthalmol* 1992;76(6):329-331.

18 Wang DD, He MG, Wu LL, Yaplee S, Singh K, Lin S. Differences in iris structural measurements among American Caucasians, American Chinese and mainland Chinese. *Clin Exp Ophthalmol* 2012;40(2):162-169.

19 Chansangpetch S, Tran B, Perez CI, *et al*. Comparison of anterior segment optical coherence tomography parameters among Vietnamese, Chinese, and whites. *Am J Ophthalmol* 2018;195:72-82.

20 Siguan-Bell CS, Chansangpetch S, Perez CI, Kutzscher A, Wang D, He M, Oldenburg C, Hee MR, Lin SC. Anterior segment parameters of Filipino-Americans compared to Chinese-Americans and Caucasian Americans using anterior segment optical coherence tomography. *Transl Vis Sci Technol* 2019;8(2):11.

21 de Silva DJ, Day AC, Bunce C, Gazzard G, Foster PJ. Randomised trial of sequential pretreatment for Nd:YAG laser iridotomy in dark irides. *Br J Ophthalmol* 2012;96(2):263-266.

22 Ono T, Iida M, Sakisaka T, Minami K, Miyata K. Effect of laser peripheral iridotomy using argon and neodymium-YAG lasers on corneal endothelial cell density: 7-year longitudinal evaluation. *Jpn J Ophthalmol* 2018;62(2):216-220.