• Clinical Research •

Pentacam changes in primary angle-closure glaucoma after different lines of treatment

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Abstract

● **AIM:** To assess the changes in the anterior chamber parameters using Pentacam following four different lines of treatment of primary angle-closure glaucoma (PACG).

● **METHODS:** A retrospective comparative study included 126 patients (126 eye) presented within 24-48h after acute angle-closure glaucoma (AACG). Patients were divided into 2 groups: group A (68 eyes) with controlled intraocular pressure (IOP) ≤21 mm Hg, which included subgroup A1 (34 eyes) with clear lens underwent Nd:YAG laser peripheral iridotomy (LPI) and subgroup A2 (34 eyes) with cataract underwent standard phacoemulsification; and group B (58 eyes) with uncontrolled IOP, which included subgroup B1 (30 eyes) with clear lens underwent trabeculectomy and subgroup B2 (28 eyes) with cataract underwent combined phacoemulsification and trabeculectomy. Patients were followed up for at least 3mo. Primary outcomes were Pentacam anterior segment measurements [anterior chamber angle (ACA) and depth (ACD)]. Secondary outcomes were changes in IOP, visual acuity (VA) and recorded complications.

● **RESULTS:** At the 3rd month, there was significant increase in the ACA values in all studied groups compared to preoperative values (P<0.001). The highest percent of increase in ACA was recorded in phacotrabeculectomy group B2 (128.40%). There was significant increase in ACD values at 3rd month compared with baseline values (P<0.001) for groups A1, A2, and B2; without change in B1 trabeculectomy group. The maximum deepening of ACD was noticed in group B2 with 94.27% increase. Significant decrease in postoperative IOP in groups A2, B1 and B2 (P<0.001, P=0.014, and P<0.001 respectively). In group A1 there was significant increase in 3rd month postoperative IOP from baseline values (P<0.001). The maximum decrease in IOP was noticed in group B2 with 59.54% decrease. VA improvement in 3rd month postoperative was recorded in all studied groups, maximum VA improvement was observed in group B2 up to 0.2 logMAR.

● **CONCLUSION:** Pentacam can be a helpful tool in studying and comparing the effect of the different lines of management of PACG on the anterior chamber measures. Phacotrabeculectomy was proved to be an effective line for managing PACG with resultant significant increase in the anterior chamber parameters, IOP reduction as well as maximum VA improvement. LPI has only temporary effect on IOP with significant changes in ACA and ACD. Phacoemuslification alone can be an option in treating PACG. Trabeculectomy resulted in temporary increase in the anterior chamber parameter which subsequently returned to baseline values.

● **KEYWORDS:** acute primary angle-closure glaucoma; laser peripheral iridotomy; phacoemulsification; trabeculectomy; phacotrabeculectomy; Pentacam

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INTRODUCTION

Acute angle-closure glaucoma (AACG) is considered an emergency ophthalmic condition characterized by sudden increase in the intraocular pressure (IOP) which may lead to sight threatening complications in a short time[1]. The initial treatment for AACG aims at rapidly reducing IOP, in order to relieve agonizing symptoms and avoid further irreversible ocular damage[2].

Once IOP has been controlled, the target of the post-AACG treatment is to prevent recurrence and prevent progression to a

Table 1 Acute primary angle-closure glaucoma[a] criteria[20]

Criteria	Details
Symptoms of an acute episode of IOP rise	Ocular pain or headache; nausea or vomiting; decreased vision rainbow-colored halos around lights.
Examination findings such as	Congested episcleral and conjunctival blood vessels; corneal epithelial edema; fixed mid-dilated, sluggish, irregular pupil and unreactive to light; shallow anterior chamber; mild amount of aqueous flare and cells.
Shallow anterior chamber and narrow angle in the other eye using three-mirror goniolens	

[a]Occurs when IOP rises rapidly as a result of relatively sudden blockage of the trabecular meshwork by the iris.

chronic condition. The definitive treatment ought to eliminate pupillary block and widen the anterior chamber angle (ACA)[3].

Laser peripheral iridotomy (LPI) had been the conventional next step in the algorithm of post-AACG management being one of the minimally invasive lines of treatments[4-6]. The efficacy of LPI in preventing recurrence of AACG as its ability to prevent progression to chronic condition has been shown to be inadequate[4]. Alternative lines of treatment are continuously studied. For decades, trabeculectomy stood as an effective method to control IOP and to stop visual field loss[7-8]. With new investigation techniques as anterior segment optical coherence tomography (AS-OCT), the role of lens vault and its association with angle closure has been more highlighted. Removal of cataractous lens facilitates aqueous outflow *via* relieving the crowded anterior segment. Thus the role of solely phacoemulsification was introduced in the paradigm of the primary angle-closure glaucoma (PACG) management[9-10]. However, combined phacotrabeculectomy was then advocated to be more effective in decreasing IOP than phacoemulsification alone[11-12].

Evaluation of the anterior chamber and angle changes in angle-closure glaucoma can aid in selecting a proper way for management. AS-OCT, ultrasonic biomicroscopy (UBM) and gonioscopy, had been routinely used to detect the morphology of the anterior chamber. Nonetheless, gonioscopy is mostly subjective and is not a reproducible method. UBM with its contact nature with the immersion technique is bothersome. Moreover, these approaches cannot provide three-dimensional (3D) view of the front of the eye[13-17].

Pentacam is a non-invasive widely available tool applying a rotating scheimpflug camera that can capture photographs from 0 to 360° giving details about anterior segment parameters as ACA and antorior chamber depth (ACD)[18-19].

Understanding anterior chamber changes in PACG can be used as a guide for selection of proper management. The purpose of this study was to compare changes of anterior chamber morphology (depth and angle) imaged by Pentacam after four different lines of treatment of PACG (LPI, phacoemulsification, trabeculectomy, and phacotrabeculectomy).

SUBJECTS AND METHODS

Ethical Approval An approval from the Ethical Committee-Mansoura University was obtained. The study is adherent to the tents of Declaration of Helsinki. Written informed consent was obtained from all the patients after thorough explanation of the procedures with their possible consequences.

Study Design and Setting A retrospective comparative observational study included patients with post-AACG presenting to the Emergency Room in Ophthalmic Center (Department of Ophthalmology at Mansoura University, Egypt) between July 2016 and September 2018.

Selection of Patients Patients eligible for the study were patients with previous attack of AACG within the previous 24-48h. All the diagnosed patients with AACG met the criteria defined in Table 1[20]. Demographic and clinical data were collected including: age, gender, visual acuity (VA), IOP and Pentacam readings (ACA and central ACD; Oculus Inc., Wetzlar, Germany). IOP was measured using Goldman applanation tonometer. VA was measured using Snellen's chart and converted to logMAR for statistical analysis.

Exclusion criteria include: 1) history of previous attacks, trauma, previous ocular surgery or previous LPI; 2) anterior segment abnormalities like corneal abnormalities, uveitis, pseudoexfoliation, neovascularization, angle abnormalities (pigmentation, recession) or pupillary block; 3) any complicated cases during or after intervention; 4) patients with incomplete follow up.

Patients were admitted and received the primary measures to control the acute attack. After 24-48h patients were examined including VA, slit lamp, gonioscopy using Shaffer grading system for the angle and IOP measurement by Goldmann applanation tonometry. All patients were still receiving topical anti-glaucoma medication (combined 0.5% timolol and 2% dorzolamide). Pentacam examinations were performed in a standard dim illumination by same skillful technician. Manual Pentacam measurements including ACD and ACA were accepted only the quality score (QS) >95%. The best of three measurements were obtained in each eye for quantitative analysis.

Patients' Grouping According to IOP and degree of angle closure using gonioscopy, patients were divided into two groups: group A had controlled IOP≤21 mm Hg and gonioscopy considered angle narrow with trabecular meshwork

Table 2 Demographic characteristics of the studied groups *n* (%)

Parameters	Laser group (A1), *n*=34	Phacoemulsification group (A2), *n*=34	Trabeculectomy group (B1), *n*=30	Phacotrabeculectomy group (B2), *n*=28	*P*
Age (y), mean±SD	59.47±7.25	61.82±9.19	57.0±5.88	60.71±8.0	0.09[a]
Gender					
Male	12 (35.3)	12 (40.0)	12 (35.3)	16 (47.1)	0.21[b]
Female	22 (64.7)	18 (60.0)	22 (64.7)	18 (52.9)	

[a]One-way ANOVA test; [b]Chi-square test. Statistically significant *P*<0.05.

was not visible in less than 50% of angle diameter, group B had IOP more than 21 mm Hg or gonioscopy considered angle closed more than 50% of angle diameter. Patients in group A were divided into subgroups A1 and A2. Subgroup A1 included patients presented with clear lens who underwent LPI using neodymium-yttrium-aluminum-garnet (Nd:YAG) laser (Laserex Tango Nd:YAG; Ellex Medical, Adelaide, Australia) and an Abraham iridotomy contact lens and received Brimonidine eye drops one hour before LPI and continued for 1wk. Subgroup A2 included patients presented with cataract who underwent standard phacoemulsification with posterior chamber IOL implantation. Patients in group B were divided into subgroup B1 with clear lens who underwent fornix based trabeculectomy; and subgroup B2 with cataract who underwent combined phacoemulsification and trabeculectomy (Figure 1). Trabeculectomy alone or in combination with phacoemulsification was done without using antimetabolites. All surgeries and laser intervention were done by multiple (four) well qualified glaucoma specialists at Mansoura Ophthalmology Center.

Postoperative Treatment and Follow-up Postoperative topical steroid and antibiotic drops were prescribed for patients in all the groups. Postoperative visits were scheduled at 1st week, 1st, and 3rd month. At each visit, VA, IOP, pentacam anterior segment measurements (ACD and ACA) were obtained.

Statistical Analysis Data were fed to the computer and analyzed using IBM SPSS software package version 22.0. Qualitative data were described using number and percent and compared with Chi-square test. Quantitative data were described using mean, standard deviation for parametric data after testing normality using Shapiro-Wilk test. One-way ANOVA test was used to compare more than 2 independent groups with post hoc Tukey test to detect pair-wise comparison. Paired *t*-test to compare between 2 measures within the same group. Significance of the obtained results was judged at <0.05 level. A sensitivity power analysis by way of a computer program (G power 3.0) presented that the effect size was 1.000 (large).

RESULTS

Demographic Data After exclusion 47 patients from the study (23 patients had incomplete follow up, 4 patients had complicated surgeries and 20 patients had previous history of acute attack), a total of 126 eyes of 126 patients were included in the study. Sixty-eight eyes were allocated in group A (34 eyes in group A1 and 34 eyes in group A2) and 58 eyes in group B (30 eyes in group B1 and 28 eyes in group B2). The majority of all the included patients were females (*n*=80/63.5%). The mean age of the patients was statistically insignificant between different groups with the oldest age in phacoemulsification group A2 (mean age 61.82±9.19y) and the youngest age in trabeculectomy group B1 (mean age 57.0±5.88y). Patients' demographic data are represented in Table 2.

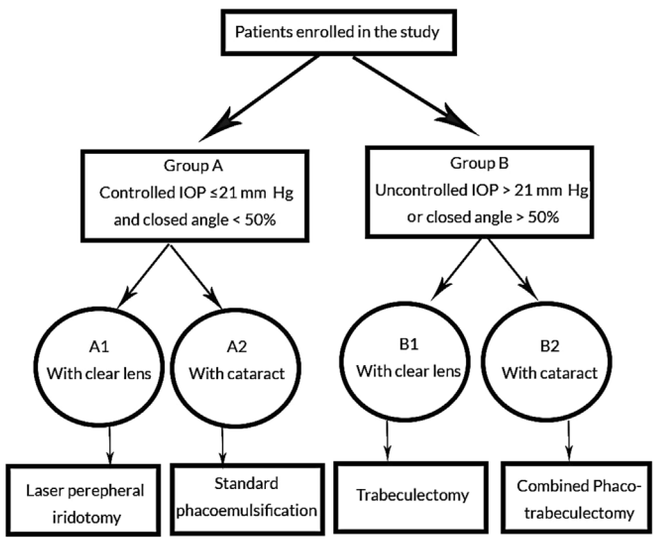

Figure 1 Enrollment of the patients among the studied groups.

Anterior Chamber Angle Maximum widening of ACA was recorded in the 1st week in all groups which remained nearly stable throughout the follow-up period. At the 3rd month, the mean ACA was higher in phacotrabeculectomy group B2 (46.57±4.22 with 128.4% increase) followed by phacoemulsification group A2 (42.81±4.41, 87.85%), laser group A1 (27.52±1.91, 13.67%) and trabeculectomy group B1 (25.15±2.35, 6.07% increase; Table 3, Figure 2).

Anterior Chamber Depth The mean ACD was approximately doubled in 1st week postoperative in phacoemulsification group A2 and phacotrabeculectomy group B2, without further significant changes along the postoperative follow up.

Table 3 IOP, ACA and ACD changes at the 3rd month postoperative from preoperative in all studied groups

Parameters	Group A1	Group A2	Group B1	Group B2	*P*1
Intraocular pressure					
Preop.	19.05±1.72[a,b]	19.26±1.85[c,d]	26.18±5.46[a,c]	27.68±6.01[b,d]	<0.001
3rd month	27.52±1.89[a,b,c]	11.89±1.26[a,d,e]	23.44±1.77[b,d,f]	11.20±1.02[c,e,f]	<0.001
Percent of change (%)	44.46	-38.26	-10.47	-59.54	
*P*2	<0.001	<0.001	0.014	0.001	
Anterior chamber angle					
Preop.	24.21±1.88[a,b,c]	22.79±3.45[a,d,e]	23.71±1.73[b,d,f]	20.39±3.47[c,e,f]	<0.001
3rd month	27.52±1.91[a,b,c]	42.81±4.41[a,d,e]	25.15±2.35[b,d,f]	46.57±4.22[c,e,f]	<0.001
Percent of change (%)	13.67	87.85	6.07	128.40	
*P*2	0.001	0.001	0.001	0.001	
Anterior chamber depth					
Preop.	1.91±0.13[a,b]	2.11±0.27[a,d]	2.04±0.15[b,c]	1.92±0.34[c,d]	0.001
3rd month	1.92±0.13[a,b]	3.54±0.33[a,c,d]	2.04±0.15[b,c,e]	3.73±0.34[b,d,e]	<0.001
Percent of change (%)	0.52	67.77	0	94.27	
*P*2	0.001	0.001	Non-applicable	0.001	

*P*1: Comparison between groups by one-way ANOVA test, similar letters in same row denote significant difference between groups with post hoc Tukey test; *P*2: Comparison within the same group by paired *t*-test. Similar letters in same row denote significant difference between groups with post hoc Tukey test.

At the 3rd month, 94.27% increase in ACD was recorded in phacotrabeculectomy B2 group and only 0.52% increase in laser A1 group. In trabeculectomy group B1, ACD remained the same as the preoperative values (0 change; Table 3, Figure 3).

Intraocular Pressure At the 3rd month, there was significant decrease in IOP in all studied groups except laser group A1 which showed increase in IOP. Phacotrabeculectomy group B2 showed the highest percent of IOP reduction at the 3rd month (59.54%), followed by phacoemulsification group A2 (38.26%). This decrease started early in the 1st week in both groups followed by minimal changes till the 3rd month. In trabeculectomy group B1, IOP significantly decreased at 1st week postoperative followed by continuous rise over the first and third month with final achievement of 10.47% IOP reduction at 3rd month. In laser group A1, IOP started to increase at the 1st week postoperative and showed minimal changes overall postoperative follow up until it gained 44.46% increase at the 3rd month. All patients in laser group received antiglaucoma medications along whole follow up period (Figure 4; Table 3).

Visual Acuity There was significant improvement in VA along postoperative follow up in phacoemulsification A1 and phacotrabeculevtomy B2 groups. There was minimal VA deterioration in the 1st week in trabeculectomy B1 group (1.4 on logMAR) and laser group A1 followed by improvement in the 1st month. The maximum VA improvement at the 3rd month follow up was recorded in the phacotrabeculectomy group B2 (0.2 logMAR; Figure 5).

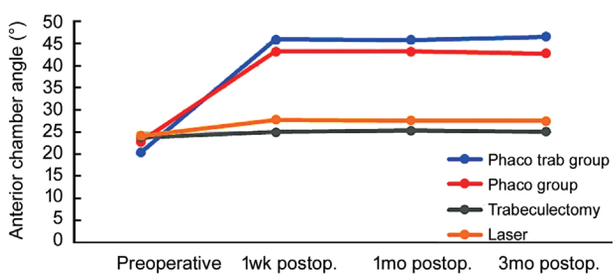

Figure 2 ACA widening (preoperative, 1wk, 1, and 3mo postoperative) in the study groups ACA: Anterior chamber angle.

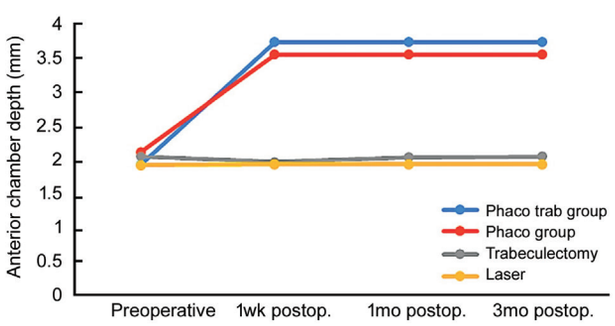

Figure 3 ACD (preoperative, 1wk, 1, and 3mo postoperative) in the study groups ACD: Anterior chamber depth.

Complications None of the included patients encountered any visual devastating complications either intra- or postoperative.

DISCUSSION

The ultimate treatment for post-AACG ought to abolish the existing pupillary block in order to prevent upcoming attacks, side by side with widening of the angle to remove any residual appositional closure to preclude further progression to chronic condition[3].

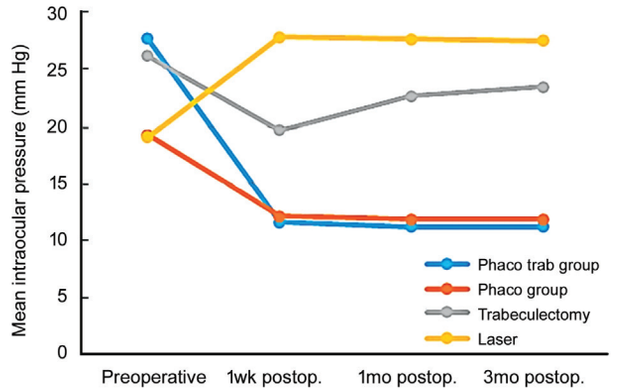

Figure 4 IOP changes (preoperative, 1wk, 1 and 3mo postoperative) in study groups.

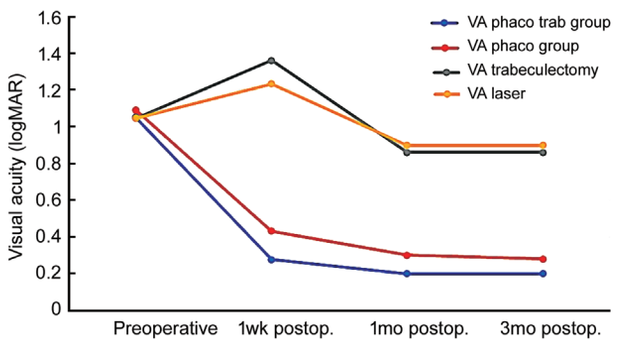

Figure 5 VA changes (preoperative, 1wk, 1, and 3mo postoperative) in the study groups.

Over the past few years, Pentacam has been used for evaluation of the anterior chamber for different purposes. The Pentacam imaging count on a rotating Scheimpflug camera that captures images of the anterior segment of the eye. It provides a complete 3D image for the anterior segment. The device's software allows objective evaluation and quantification of the anterior segment parameters as central ACD, peripheral ACD, anterior chamber volume and ACA. All these objective measurements are carried in a noncontact method within merely 2s[19].

The aim of our study was to use the Pentacam to detect the changes in the anterior chamber morphology after 4 different lines of treatment of PACG. We included 126 eyes post- acute angle-closure attack treated with LPI, phacoemulsification, trabeculectomy and phacotrabeculectomy. All patients were followed for at least 3mo. Allocation of the patients in the groups was based on IOP control and degree of angle closure together with the lens status. Baseline and postoperative Pentacam measures of the anterior chamber including ACA and ACD were recorded and compared together with IOP and VA.

LPI proved to have a role in treating PACG as well as preventing the progression of primary angle-closure (PAC) into PACG[5-6]. LPI creates an opening within the periphery of the iris with subsequent flattening of the convex iris and widening the ACA[15]. Yet, quantification of changes following LPI was previously hampered by the inefficiency of the available instruments. Using Pentacam in the present study revealed significant increase in the width and depth of ACA in eyes treated with LPI. Similar significant increase in the ACA was reported in study by Li *et al*[21]. Though the ACD in our study showed only minimal widening, the difference was statistically significant owing to the sample size. Unterlauf *et al*'s[22] study reported also significant increase in ACD 2d following LPI. Other studies enrolling PAC suspects reporting insignificant changes in central ACD after LPI and assumed that the LPI only affects the convexity of the iris while the lens plane remains unchanged, thus no effect can be predicted in the central ACD[21,23-24] . However the flattening of the iris after LPI pushes the iris backwards in the peri-pupillary region as well as the medium and the peripheral parts[25].

Regarding IOP control after LPI, our results showed increase in IOP at the 3rd month. IOP elevation >21 mm Hg within 6mo was reported previously in several studies[26-33]. Besides, Friedman *et al*[34] documented that 8% of fellow eyes of AACG required further glaucoma surgery after PLI. Chen *et al*[35] followed eyes after LPI for around 36mo and concluded that eyes with PACG required additional medical treatment and surgical interference on the long term. Iris thickness, inflammatory or structural angle damage are possible causes for this elevation of IOP[35-38].

The role of lens in the mechanism of development of AACG has been widely advocated. The thick crystalline lens might cause angle closure *via* narrowing of ACD as well as the ACA. Hence, the effects of cataract surgery on IOP levels in non-glaucomatous eyes were evaluated by several studies[39-41]. These studies showed that phacoemulsification alone could significantly induced IOP reduction. Furthermore, the role of phacoemulsification in widening the drainage angle and deepening of the anterior chamber in PACG eyes was reported by several studies[42-44]. Hayashi *et al*[45] noticed that most of the changes in anterior chamber parameters occured at the first month post-surgery with almost no change till the end of their study. Our results showed greater widening of angle after phacoemulsification than Hayashi's results (42.81° and 35.7° respectively) and more decrease of IOP (11.89 mm Hg and 15.00 mm Hg respectively). This difference may be related to the preoperative wider angle and lower IOP in our patients than Hayashi's study.

Our study showed that trabeculectomy induced minor changes in the anterior segment parameters in the 1st postoperative week that returned to their baseline values in the 1st postoperative month and remained stable till the 3rd postoperative month. Studies utilizing the Haag-Streit pachymetry have shown that ACD reaches its shortest value on the 2nd and 3rd days after trabeculectomy then started deepening thereafter to reach its

baseline preoperative value by the 2nd week[46-47]. Simsek *et al*[48] used Pentacam to assess 38 phakic patients with primary open angle glaucoma after trabeculectomy surgery and noticed that ACD and ACA decreased in first postoperative week then increased at first postoperative month to preoperative base line value.

According to Diagourtas *et al*'s[49] study, IOP was reduced from 24.21±6.0 preoperative to 12.00±2.57 at 2nd month after trabeculectomy with 47.52% reduction. Post-trabeculectomy IOP in our study showed 10.47% reduction at 3rd month. Anti-metabolites were not used in any of our patients. This may be a reason for the lower IOP reduction rate in our series.

Trabeculectomy surgery alone and phacoemulsification alone help in opening ACA, but maximized effect is noticed if both are combined together. In one Meta-analysis study[50] phacotrabeculectomy had better IOP control than did either phacoemulsification or trabeculectomy alone. This was in agreement with our results. However, in the Meta-analysis there was insignificant change in ACD and ACA following phacotrabeculectomy which was in contrast to our results.

Scrutinizing our results revealed that, Pentacam could be a useful tool for evaluating the anterior chamber in both qualitative and quantitative aspects with the advantages of being objective, easy in handling, attained with a speedy, non-contact method.

The current study has some limitations as the retrospective design and the short duration of follow up. Also, the measurements of peripheral ACD, iris thickness, and lens thickness were not included. However, up to our vast knowledge, this is the first study comparing the four lines of treatment of the PACG using Pentacam. Large number of included participants may add to the relevance of the results.

In conclusion, Pentacam can be a helpful tool in studying and comparing the effect of the different lines of management of PACG on the anterior chamber measures. Phacotrabeculectomy was proved to be an effective line for managing PACG with resultant significant increase in the anterior chamber parameters, IOP reduction as well as maximum VA improvement. LPI has only temporary effect on IOP with significant changes in ACA and ACD. Phacoemuslification alone can be an option in treating PACG. Trabeculectomy resulted in temporary increase in the anterior chamber parameter which subsequently returned to baseline values.

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Conflicts of Interest: Mokbel TH, None; **Elhesy A,** None; **Alnagdy A,** None; **Elashri M,** None; **Eissa A,** None; **Gaafar WM,** None; **Hagras SM,** None.

REFERENCES

1 David R, Tessler Z, Yassur Y. Long-term outcome of primary acute angle-closure glaucoma. *Br J Ophthalmol* 1985;69(4):261-262.

2 Ang LP, Ang LP. Current understanding of the treatment and outcome of acute primary angle-closure glaucoma: an Asian perspective. *Ann Acad Med Singap* 2008;37(3):210-215.

3 Aung T, Ang LP, Chan SP, Chew PT. Acute primary angle-closure: long-term intraocular pressure outcome in Asian eyes. *Am J Ophthalmol* 2001;131(1):7-12.

4 Ang GS, Wells AP. Changes in Caucasian eyes after laser peripheral iridotomy: an anterior segment optical coherence tomography study. *Clin Exp Ophthalmol* 2010;38(8):778-785.

5 Thompson C, Vu M, Cowan A, Asrani S. Factors associated with interventions after laser peripheral iridotomy for primary angle-closure spectrum diagnoses. *Ophthalmology Glaucoma* 2019;2(3):192-200.

6 Kansara S, Blieden LS, Chuang AZ, Baker LA, Bell NP, Mankiewicz KA, Feldman RM. Effect of laser peripheral iridotomy on anterior chamber angle anatomy in primary angle closure spectrum eyes. *J Glaucoma* 2016;25(5):e469-e474.

7 Hong JX, Chen JY, Yang YJ, Wei AJ, Kong XM, Yu XB, Jiang CH, Liu ZG, Sun XH, Xu JJ. Optical coherence tomography assessment of angle anatomy changes after trabeculectomy in primary angle-closure glaucoma. *J Glaucoma* 2016;25(3):244-247.

8 Nguyen DQ, Niyadurupola N, Tapp RJ, O'Connell RA, Coote MA, Crowston JG. Effect of phacoemulsification on trabeculectomy function. *Clin Exp Ophthalmol* 2014;42(5):433-439.

9 Nongpiur ME, Atalay E, Gong T, Loh M, Lee HK, He M, Perera SA, Aung T. Anterior segment imaging-based subdivision of subjects with primary angle-closure glaucoma. *Eye (Lond)* 2017;31(4):572-577.

10 Kim YK, Yoo BW, Kim HC, Aung T, Park KH. Relative lens vault in subjects with angle closure. *BMC Ophthalmol* 2014;14:93.

11 Tham CC, Kwong YY, Leung DY, Lam SW, Li FC, Chiu TY, Chan JC, Chan CH, Poon AS, Yick DW, Chi CC, Lam DS, Lai JS. Phacoemulsification versus combined phacotrabeculectomy in medically controlled chronic angle closure glaucoma with cataract. *Ophthalmology* 2008;115(12):2167-2173.e2.

12 Tham CC, Kwong YY, Leung DY, Lam SW, Li FC, Chiu TY, Chan JC, Lam DS, Lai JS. Phacoemulsification versus combined phacotrabeculectomy in medically uncontrolled chronic angle closure glaucoma with cataracts. *Ophthalmology* 2009;116(4):725-731,731.e1-3.

13 Vryonis N, Nikita E, Vergados I, Theodossiadis P, Filippopoulos T. Anterior chamber morphology before and after laser peripheral iridotomy determined by Scheimpflug technology in white patients with narrow angles. *J Glaucoma* 2013;22(9):679-683.

14 Yao BQ, Wu LL, Zhang C, Wang X. Ultrasound biomicroscopic features associated with angle closure in fellow eyes of acute primary angle closure after laser iridotomy. *Ophthalmology* 2009;116(3):444-448.e2.

15 He MG, Friedman DS, Ge J, Huang WY, Jin CJ, Cai XY, Khaw PT, Foster PJ. Laser peripheral iridotomy in eyes with narrow drainage angles: ultrasound biomicroscopy outcomes. The Liwan Eye Study. *Ophthalmology* 2007;114(8):1513-1519.

16 Dada T, Mohan S, Sihota R, Gupta R, Gupta V, Pandey RM. Comparison of ultrasound biomicroscopic parameters after laser iridotomy in eyes with primary angle closure and primary angle closure glaucoma. *Eye (Lond)* 2007;21(7):956-961.

17 Talajic JC, Lesk MR, Nantel-Battista M, Harasymowycz PJ. Anterior segment changes after pilocarpine and laser iridotomy for primary angle-closure suspects with scheimpflug photography. *J Glaucoma* 2013;22(9):776-779.

18 Esmaeili A, Barazandeh B, Ahmadi S, Haghi A, Ahmadi Hosseini SM, Abolbashari F. Assessment of the anterior chamber parameters after laser iridotomy in primary angle close suspect using Pentacam and gonioscopy. *Int J Ophthalmol* 2013;6(5):680-684.

19 Hashemi H, Yekta A, Khodamoradi F, Aghamirsalim M, Asharlous A, Assadpour M, Khabazkhoob M. Anterior chamber indices in a population-based study using the Pentacam. *Int Ophthalmol* 2019;39(9):2033-2040.

20 Cioffi G, Durcan F, Girkin C. Basic and Clinical Science Course, Section 10: Glaucoma. New York: American Academy of Ophthalmology 2011;1st,57-63.

21 Li XY, Wang Z, Cao Q, Hu L, Tian F, Dai H. Pentacam could be a useful tool for evaluating and qualifying the anterior chamber morphology. *Int J Clin Exp Med* 2014;7(7):1878-1882.

22 Unterlauft JD, Yafai Y, Wiedemann P. Changes of anterior chamber architecture induced by laser peripheral iridotomy in acute angle closure crisis. *Int Ophthalmol* 2015;35(4):549-556.

23 Aboleila A, El-Sharkawy H, Abd El Ghafar A, Ghanem A. Evaluation of anterior segment changes following laser peripheral iridotomy by scheimpflug imaging. *ARC J Ophthalmology* 2018;3(2):13-16.

24 Jain R, Grewal D, Grewal SP. Quantitative analysis of anterior chamber following peripheral laser iridotomy using Pentacam in eyes with primary angle closure. *Eur J Ophthalmol* 2012:0.

25 López-Caballero C, Puerto-Hernández B, Muñoz-Negrete FJ, Rebolleda G, Contreras I, Cabarga C, Corral A. Quantitative evaluation of anterior chamber changes after iridotomy using Pentacam anterior segment analyzer. *Eur J Ophthalmol* 2010;20(2):327-332.

26 Nolan WP, Foster PJ, Devereux JG, Uranchimeg D, Johnson GJ, Baasanhu J. YAG laser iridotomy treatment for primary angle closure in east Asian eyes. *Br J Ophthalmol* 2000;84(11):1255-1259.

27 Pandav SS, Kaushik S, Jain R, Bansal R, Gupta A. Laser peripheral iridotomy across the spectrum of primary angle closure. *Can J Ophthalmol* 2007;42(2):233-237.

28 Ramani KK, Mani B, George RJ, Lingam V. Follow-up of primary angle closure suspects after laser peripheral iridotomy using ultrasound biomicroscopy and A-scan biometry for a period of 2 years. *J Glaucoma* 2009;18(7):521-527.

29 Peng PH, Nguyen H, Lin HS, Nguyen N, Lin S. Long-term outcomes of laser iridotomy in Vietnamese patients with primary angle closure. *Br J Ophthalmol* 2011;95(9):1207-1211.

30 Lam DS, Leung DY, Tham CC, Li FC, Kwong YY, Chiu TY, Fan DS. Randomized trial of early phacoemulsification versus peripheral iridotomy to prevent intraocular pressure rise after acute primary angle closure. *Ophthalmology* 2008;115(7):1134-1140.

31 Aung T, Friedman DS, Chew PT, Ang LP, Gazzard G, Lai YF, Yip L, Lai H, Quigley H, Seah SK. Long-term outcomes in asians after acute primary angle closure. *Ophthalmology* 2004;111(8):1464-1469.

32 Lai JS, Tham CC, Chua JK, Poon AS, Chan JC, Lam SW, Lam DS. To compare argon laser peripheral iridoplasty (ALPI) against systemic medications in treatment of acute primary angle-closure: mid-term results. *Eye (Lond)* 2006;20(3):309-314.

33 Tan AM, Loon SC, Chew PT. Outcomes following acute primary angle closure in an Asian population. *Clin Exp Ophthalmol* 2009;37(5):467-472.

34 Friedman DS, Chew PT, Gazzard G, Ang LP, Lai YF, Quigley HA, Seah SK, Aung T. Long-term outcomes in fellow eyes after acute primary angle closure in the contralateral eye. *Ophthalmology* 2006;113(7):1087-1091.

35 Chen MJ, Cheng CY, Chou CK, Liu CJ, Hsu WM. The long-term effect of Nd: YAG laser iridotomy on intraocular pressure in Taiwanese eyes with primary angle-closure glaucoma. *J Chin Med Assoc* 2008;71(6):300-304.

36 Jiang Y, Chang DS, Foster PJ, He M, Huang S, Aung T, Friedman S. Immediate changes in intraocular pressure after laser peripheral iridotomy in primary angle-closure suspects. *Ophthalmology* 2012;119(2):283-288.

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

38 Rao A, Rao HL, Kumar AU, Babu JG, Madhulata U, Arthi J, Tukaram M, Senthil S, Garudadri CS. Outcomes of laser peripheral iridotomy in angle closure disease. *Semin Ophthalmol* 2013;28(1):4-8.

39 Uçakhan OO, Ozkan M, Kanpolat A. Anterior chamber parameters measured by the Pentacam CES after uneventful phacoemulsification in normotensive eyes. *Acta Ophthalmol* 2009;87(5):544-548.

40 Doganay S, Bozgul Firat P, Emre S, Yologlu S. Evaluation of anterior segment parameter changes using the Pentacam after uneventful phacoemulsification. *Acta Ophthalmol* 2010;88(5):601-606.

41 Dooley I, Charalampidou S, Malik A, Loughman J, Molloy L, Beatty S. Changes in intraocular pressure and anterior segment morphometry after uneventful phacoemulsification cataract surgery. *Eye (Lond)* 2010;24(4):519-526; quiz 527.

42 Moghimi S, Hashemian H, Chen R, Johari M, Mohammadi M, Lin SC. Early phacoemulsification in patients with acute primary angle closure. *J Curr Ophthalmol* 2015;27(3-4):70-75.

43 Di Staso S, Sabetti L, Taverniti L, Aiello A, Giuffrè I, Balestrazzi E. Phacoemulsification and intraocular lens implant in eyes with primary angle-closure glaucoma: our experience. *Acta Ophthalmol Scand Suppl* 2002;236:17-18.

44 Man XF, Chan NC, Baig N, Kwong YY, Leung DY, Li FC, Tham CC. Anatomical effects of clear lens extraction by phacoemulsification

versus trabeculectomy on anterior chamber drainage angle in primary angle-closure glaucoma (PACG) patients. *Graefes Arch Clin Exp Ophthalmol* 2015;253(5):773-778.

45 Hayashi K, Hayashi H, Nakao F, Hayashi F. Changes in anterior chamber angle width and depth after intraocular lens implantation in eyes with glaucoma. *Ophthalmology* 2000;107(4):698-703.

46 Peng SX, Zhou WB. The anterior chamber depth after trabeculectomy. *Zhonghua Yan Ke Za Zhi* 1992;28(4):214-216.

47 Martínez-Belló C, Rodriguez-Ares T, Pazos B, Capeáns C, Sánchez-Salorio M. Changes in anterior chamber depth and angle width after filtration surgery: a quantitative study using ultrasound biomicroscopy. *J Glaucoma* 2000;9(1):51-55.

48 Simsek M, Elgin U, Uzel MM, Sen E, Yilmazbas P. Stabilization time of anterior segment parameters after trabeculectomy surgery. *Eye Contact Lens* 2018;44(Suppl 2):S396-S399.

49 Diagourtas A, Papaconstantinou D, Vergados A, Andreanos K, Koutsandrea C. Objective documentation of anterior chamber depth following trabeculectomy and its correlation with intraocular pressure and bleb functionality. *Medicine (Baltimore)* 2018;97(34):e11824.

50 Verma J, John D, Nair SR, Oomman S, Mishra R, Shah P, Jha D, Shaikh S. Efficacy and safety of surgical treatment options for primary angle closure glaucoma: a meta-analysis of randomised controlled trials. *Value Heal* 2015;18(7):A415-A416.