Ultrasound Biomicroscopic Changes of the Angle after Laser Iridotomy and Primary Trabeculectomy in Primary Angle Closure Glaucoma Patients

SAFWAT ELKADY, M.D.
The Department of Ophthalmology, Faculty of Medicine, Cairo University

Abstract

Purpose: To study the morphological changes of the angle structure after laser iridotomy (LI) and primary trabeculectomy (PT) in primary angle-closure glaucoma (PACG) using ultrasound biomicroscopy (UBM).

Method: Thirty patients with primary angle-closure glaucoma (PACG) were prospectively enrolled in this study. They were divided into two groups; the first group consisted of 14 patients who had undergone laser iridotomy. The second group consisted of 16 patients who had undergone trabeculectomy surgery. Patients underwent anterior segment evaluation including gonioscopy, disc evaluation with+90D lens, application intraocular pressure. Ultrasound biomicroscopy study was performed for each patient before and two weeks after the procedure. Parameters which were assessed included Trabecular-iris angle (TIA) (theta1), Central anterior chamber depth (ACD), Angle-opening distance at a point 500 µm from the scleral spur (AOD500), trabecular ciliary process distance (TCPD), ciliary process-iris angle (CPI), iris thickness (ID 1, ID3) and length of iris-lens contact distance (ILCD).

Results: There were statistically significant increases in AOD500, (TIA) theta1, and ILCD in both groups. CPI was decreased in both groups. ACD, TCPD, and iris thickness were not changed significantly. The changes in angle configuration after LI or PT may result more from alterations in aqueous pressure gradients across the iris. However, no significant differences in the changes of parameters between the two procedures had been found except for postoperative CPI (p=0.019), indicating that the degree of iris moving back was less in the PT group than in the LI group.

Conclusion: UBM gives an accurate and objective documentation of the changes in the anterior segment induced by an LPI and Primary trabeculectomy in PACG. The mechanism of action of an LPI is that it creates an opening to bypass the pupillary block and thereby allows a convex iris to flatten and widen the anterior chamber angle.

Key Words: Laser iridotomy – Primary trabeculectomy – Primary angle-closure glaucoma ultrasound biomicroscopy – Angle structure.

Introduction

COMPARED with normal eyes, eyes with primary angle-closure glaucoma (PACG) show an increased lens thickness and a more anteriorly situated lens, the latter of which may be associated with anteriorly situated ciliary process [1,2,3]. Relative pupillary block and iris crowding are involved in the development of angle closure in PACG. Ultrasound biomicroscopy (UBM) is usually able to determine the mechanism of elevated intraocular pressure (IOP) by showing the relationship between the peripheral iris and the trabecular meshwork.

Primary angle-closure glaucoma (PACG) is the major form of glaucoma and an important cause for blindness worldwide [1]. The development of primary angle closure (PAC) into PACG can be prevented by performing a laser peripheral iridotomy (LPI) [2,3]. This is especially useful in preventing recurrence of acute attacks and eliminating the risk of an acute attack in eyes with intermittent angle closure or predisposed fellow eyes [2,3]. In eyes with PAC, an LPI may help in reversing appositional angle closure and control the intraocular pressure (IOP) [2,3]. The mechanism of action of an LPI is that it creates an opening to bypass the pupillary block and thereby allows a convex iris to flatten and widen the anterior chamber angle [2,3].

However, there has been no accurate and objective documentation of the changes in anterior chamber angle morphology induced by an LPI or by Primary trabeculectomy in PACG. Gonioscopic studies are limited by observer bias and do not allow for an accurate estimation of the angle recess. Ultrasound biomicroscopy (UBM) is a high-resolution imaging of the anterior segment that allows an objective evaluation of the angle mor-
Ultrasound Biomicroscopic Changes of the Angle after Laser Iridotomy

UBM measurements were made at the time of arrival, and 2 weeks after LI or PT had been done. Topical instillation of 4% pilocarpine, beta-blockers, and carbonic anhydrase inhibitors were done before UBM examination.

The parameters of the UBM (UBM was carried out utilizing Ultrasound biomicroscope (Model UBM Model 840 machine (Paradigm medical Industries, Inc, USA) were set at:

- 5.0X5.0mm field of view with 90 decibels of gain, 5dB gains compensation with approximately 50 µm resolution and 2.24mm delay.
- The patient in supine position during the examination. Topical anaesthesia with 0.5% proparacaine had been used.
- Using an eye cup filled with 1.5% Methyl cellulose and physiologic saline.
- We scanned 4 positions of the angle; at 3, 6, 9 and 12 o’clock positions with care taken not to exert pressure on the globe. Variation in accommodation was minimized by fixation with the contralateral eye on a standard distance target on the ceiling. All measurements were made in each eye in its axial section with the probe kept perpendicular to the corneo-scleral surface in constant ambient lighting, through a typical ciliary process, and as vertically as possible, as determined by observing the screen image. The scleral spur is particularly useful as a constant reference point for measurement of the angle region. Areas with peripheral anterior synechiae formation and a completely closed angle were avoided and only images with a visible angle recess were included for measurements. An image centered on the pupil was also captured. The various anterior segment parameters listed below, were measured on these images using a caliper incorporated within the instrument’s software package. The procedure was repeated 2 weeks after performing an LPI and the PT. The UBM images pre- and post-LPI and PT were taken by me in the UBM unit in King Abdel Aziz University Hospital.

The ocular measurements taken by the UBM included:

- The trabecular-iris angle (TIA) (O1) measured with its apex in the iris recess and the arms of the angle passing through a point on the trabecular meshwork at 500 µm from the scleral spur and the point on the iris perpendicularly opposite.
- The trabecular-ciliary process distance (TCPD), measured on a line extending from the corneal endothelium at 500 µm from the scleral spur perpendicularly through the iris to the ciliary processes.

Material and Methods

Thirty patients with PACG had been studied prospectively; the patients had no previous treatment with laser or incisional surgery. Patients of secondary ACG due to lens abnormalities, retinal surgery, or other causes were excluded. Patients were classified into the LI group formed of 14 patients and PT groups formed of 16 patients. In the LI group, LI was only performed. In the PT group, PT was performed when IOP was uncontrolled by glaucoma medications and LI.

Consecutive patients of PACG attending the glaucoma clinic service of King Abdel Aziz University Hospital from February 2009 to March 2011 were included in the present study. The diagnosis was based on clinical history, slit lamp and ophthalmoscopic examinations, gonioscopy, IOP measurement, and visual field testing.

Those patients included in the study had a chronically elevated IOP (>21mmHg), gonioscopically confirmed peripheral anterior synechiae of more than 180°, and optic nerve head and visual field changes typical of glaucoma.

All cases underwent a detailed eye examination including measurement of visual acuity, slit-lamp biomicroscopy, direct ophthalmoscopy, 90D fundus examination, gonioscopy, applanation tonometry, visual field testing (Humphrey 30-2 test), A-scan biometry.
• The AOD 500 is the distance between the posterior corneal surface and the anterior iris surface measured on a line perpendicular to the trabecular meshwork 500 μm from the scleral spur.

• The ICPD is the distance measured from the posterior iris surface (iris pigmented epithelium to the ciliary process along the same line as the TCPD.

• The ILCD, measured along the iris pigmented epithelium from the pupillary border to the point where the anterior lens surface leaves the iris.

• The ILA corresponds to the angle between the iris and the lens near the pupillary edge.

• IT, Iris thickness was measured 1mm from the iris root (ID 1) and at its thickest point near the margins (ID3) measured.

• Central ACD was measured by a perpendicular drawn from the posterior corneal surface up to a horizontal line parallel to the edge of the pupil.

• Ciliary process-iris angle (CPI) is the angle between the iris and the ciliary process, measured with two lines. One line made from the point of half of ID 1 and ID3, the other line made from the point of half of the ciliary process at the line of scleral spur and trabecular meshwork at 500 µm with zonular attachment.

The LI was performed using a Nd: YAG (neodymium-yttrium-aluminium-garnet) laser set at 2-6mJ. A Crypt in the midperipheral iris was selected for the iridotomy site. All patients received 0.1% betamethasone eye drops (q.i.d.) for 1 week in addition to the anti-glaucoma medications they were already receiving (excluding pilocarpine). Patients were given 0.5% timolol eye drops (b.i.d.) for a 1-week period after the LI.

The primary trabeculectomy group had undergone classic subscleral trabeculectomy with peripheral iridectomy.

All of the cases of LP group and PT group cases had been evaluated preoperatively by me and then operated upon by different surgeons in King Abdel Aziz University Hospital. And then referred back to postoperative UBM by me.

Statistical analysis was performed using STATA version 8.0 program and a p-value of <0.5 was taken as statistically significant. Wilcoxon’s-Sign-Rank test and t-test were used to analyze the UBM parameters and to compare each parameter before and after each procedure, and to compare each parameter between the two procedure groups.

Results

Fourteen patients with LI (mean age: 59.30 ± 8.16 years) and sixteen with PT (mean age: 63.75 ± 6.95 years) were prospectively enrolled in the study as shown in Table (1).

Table (1): Patient’s demographics.

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of pts</th>
<th>Male</th>
<th>Female</th>
<th>Mean age (Y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Iridotomy</td>
<td>14</td>
<td>6</td>
<td>8</td>
<td>59.30±8.16</td>
</tr>
<tr>
<td>Primary trabeculectomy</td>
<td>16</td>
<td>8</td>
<td>8</td>
<td>63.75±6.95</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>14</td>
<td>16</td>
<td>56.5±12</td>
</tr>
</tbody>
</table>
Mean preoperative IOP was 38±17.5mmHg and 40±16.5mmHg, and mean postoperative IOP was 15.2±3.8mmHg and 16.5±4.2mmHg in the LI and PT groups, respectively at 3 weeks postoperatively and 17±2.7 and 14.3±4.8 at 3 months postoperatively in the LI and PT groups, respectively (Table 2). There was no statistically significant difference in IOP between the two groups as shown in Table (2).

Table (2): Mean preoperative and postoperative intraocular pressures (mmHg) in the laser iridotomy and trabeculectomy groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Preoperative</th>
<th>Postoperative 3 weeks</th>
<th>Postoperative 3 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Iridotomy</td>
<td>38±17.5</td>
<td>15.2±3.8</td>
<td>17±2.7</td>
</tr>
<tr>
<td>Primary trabeculectomy</td>
<td>40±16.5</td>
<td>16.5±4.2</td>
<td>14.3±4.8</td>
</tr>
</tbody>
</table>

Table (3): Mean preoperative and postoperative ultrasound biomicroscopy (UBM) parameters in the laser iridotomy group.

<table>
<thead>
<tr>
<th>UBM parameter</th>
<th>Pre LPI (mean)</th>
<th>Post LPI (mean)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>†TIA (deg)</td>
<td>11.92±3.40°</td>
<td>27.31±5.23°</td>
<td>0.0001</td>
</tr>
<tr>
<td>*AOD500 (mm)</td>
<td>0.107±0.09</td>
<td>0.208±0.18</td>
<td>0.0001</td>
</tr>
<tr>
<td>‡TCPD (mm)</td>
<td>0.748±0.19</td>
<td>0.837±0.19</td>
<td>0.0001</td>
</tr>
<tr>
<td>**ITT (mm)</td>
<td>0.473±0.08</td>
<td>0.486±0.11</td>
<td>0.42</td>
</tr>
<tr>
<td>*CPI (deg)</td>
<td>26.15±7.89</td>
<td>4.39±1.22°</td>
<td>0.019</td>
</tr>
<tr>
<td>#ILCD (mm)</td>
<td>0.605±0.10</td>
<td>1.053±0.106</td>
<td>0.0174</td>
</tr>
<tr>
<td>†ACD (mm) central</td>
<td>2.19±0.36</td>
<td>2.30±0.36</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

†: Trabecular-iris angle.  
*: Angle-opening distance at a point 500mm from the scleral spur.  
‡: Trabecular ciliary process distance.  
**: Iris thickness.  
*: Ciliary process-iris angle.  
#: Length of iris-lens contact distance.  
†: Anterior chamber depth (central).

Table (4): Mean preoperative and postoperative ultrasound biomicroscopy (UBM) parameters in the trabeculectomy group.

<table>
<thead>
<tr>
<th>UBM parameter</th>
<th>Pre trabeculectomy (mean)</th>
<th>Post trabeculectomy (mean)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>†TIA (deg)</td>
<td>9.33±3.88°</td>
<td>25.30±2.07°</td>
<td>0.0001</td>
</tr>
<tr>
<td>*AOD500 (mm)</td>
<td>0.065±0.09</td>
<td>0.076±0.13</td>
<td>0.0001</td>
</tr>
<tr>
<td>‡TCPD (mm)</td>
<td>0.756±0.26</td>
<td>0.829±0.26</td>
<td>0.343</td>
</tr>
<tr>
<td>**ITT (mm)</td>
<td>0.492±0.12</td>
<td>0.484±0.096</td>
<td>0.195</td>
</tr>
<tr>
<td>*CPI (deg)</td>
<td>24.17±7.76</td>
<td>11.17±6.91°</td>
<td>0.014</td>
</tr>
<tr>
<td>#ILCD (mm)</td>
<td>0.588±0.067</td>
<td>0.980±0.128</td>
<td>0.08</td>
</tr>
<tr>
<td>†ACD (mm) central</td>
<td>1.79±0.32</td>
<td>1.82±0.33</td>
<td>0.131</td>
</tr>
</tbody>
</table>

†: Trabecular-iris angle.  
*: Angle-opening distance at a point 500mm from the scleral spur.  
‡: Trabecular ciliary process distance.  
**: Iris thickness.  
*: Ciliary process-iris angle.  
#: Length of iris-lens contact distance.  
†: Anterior chamber depth (central).

There were statistically significant increases in AOD500 and O1 in both groups after each procedure: Preoperative AOD500 was 0.107±0.09mm and 0.065±0.09mm and postoperative AOD500 was 0.208±0.18mm and 0.076±0.13mm; preoperative O1 was 11.92±3.40° and 9.33±3.88°, and postoperative O1 was 27.31±5.23° and 25.30±2.07° in LI and PT, respectively (Tables 2,3).

ACD (central) and TCPD were slightly increased, but there was no statistical significance: preoperative ACD was 2.19±0.36mm and 1.79±0.32mm, and postoperative ACD was 2.30±0.36mm and 1.82±0.33mm; preoperative TCPD was 0.748±0.19mm and 0.756±0.26mm, and postoperative TCPD was 0.837±0.19mm and 0.829±0.26mm in LI and PT, respectively.

CPI was decreased from 26.15±7.89 to 4.39±1.22° in LI, and from 24.17±7.76 to 11.17±6.91° in PT.

ILCD was increased significantly from 0.605±0.10mm to 1.053±0.106mm in LI and from 0.588±0.067mm to 0.980±0.128mm in PT.

Iris thickness (ID1 and ID3) was not changed after either procedure.

There were no significant differences in parameters before and after both procedures except postoperative CPI (p=0.019) in the LI group.

**Discussion**

To date few studies had reported the changes of the angle after laser iridotomy and primary trabeculectomy in primary angle closure glaucoma patients using UBM.

In previous biometric studies in eyes with angle closure glaucoma, primary angle closure glaucoma characterized by a shorter axial length and a thicker more anteriorly positioned lens [1,4,7,8].

Studies comparing the angle in patients with angle closure glaucoma with normal patients with open-angle using UBM demonstrated the presence of forward rotation of ciliary process. The location of the iris insertion and fragility of the iris root are the most important parameters to describe the mechanisms of appositional angle closure glaucoma [17,8].

Pupillary block is the predominant mechanism of acute PACG. LI or PT with peripheral LI may deepen the anterior chamber by releasing the pupillary block. The effect of LI is to eliminate the posterior-anterior pressure difference across the iris [2,3].
In eyes with acute attack, a forward movement of the lens contributes to the initiation of the attack, causing greater iris convexity. So, the attacks result from small anatomic dimensions and an additional physiological event that causes anterior lens movements [9].

Salmon et al. [10], studying 46 patients, all with chronic PACG, found that the lenses were the same thickness as in normal subjects, that a relatively anterior lens position, rather than a large lens, was responsible for the crowded anterior segment in the chronic PACG patients and that a more anteriorly situated ciliary process might be a racial characteristic of the ethnic group studied.

The present study demonstrated clearly that there are statistically significant increases in AOD500 and O1 after LI or PT in both groups after each procedure. Other similar studies confirm this finding. Yoon et al. [11] reported a statistically significant increases in AOD500, O1, and ILCD in 13 eyes with PACG.

An opening of the iris effectively carries aqueous flow without significant resistance. The typical flat peripheral configuration of the iris without a pressure difference is detected by gonioscopy or ultrasound imaging [12]. The angle was opened after releasing the pupillary block, which was evidenced by an increase in the angle opening distance at 500 µm (AOD 500) and the increase in O1.

Elimination of the trans-iris pressure differential might alter the lens position slightly. However, ultrasound studies demonstrated that the lens did not move posterior after LI or PT [13]. Furthermore, there were some cases that the IOP still remained high with anteriorly positioned lens after both procedures. So, it is presumed that some factors that might induce the lens to move forward still remains or could not be corrected by LI or PT. This means that the potential risk of attack still remains after both procedures.

In this study, central ACD was not increased significantly after LI or PT. The central ACD has not been known to change acutely with LI in primary angle closure eyes [9,13].

Previous studies that measured central ACD before and after LI or PT found no significant deepening [14]. While some studies were confounded by the use of miotic eye drops, the prevailing conclusion was that the lens did not move posteriorly after LI [14]. The tendency for the lens to move anteriorly in acute attacks, and potentially in the chronic form of the disease as well may be derived from expansion of the choroids, which might be contributing factors in malignant glaucoma [9]. However, the position of the lens is one of the important factors in the ACG mechanism. One part of the evidence of lens factor is that cataract extraction lowers IOP by improving the angle configurations in ACG [15,16].

Gazzard et al. [17] studied the effect of LPI on 55 fellow eyes of acute PACG patients. The AOD500 and angle recess area all significantly increased after sequential laser iridotomy but the ACD did not change significantly (2.41 vs. 2.42mm) as measured with optical pachymetry. The authors concluded that in Asian eyes at high risk of developing acute PAC, LPI produced a significant widening of the anterior chamber angle without deepening the anterior chamber centrally.

Yoon et al. [11] reported a statistically significant increases in AOD500, TIA, and ILCD in 13 eyes with PACG, but the ACD, TCPD, and IT were not changed significantly in PACG. The changes in angle configuration after LPI were reported to be due to alterations in aqueous pressure gradients across the iris.

In the study, TCPD was slightly increased after LI or PT. CPI was decreased after both procedures. It had been anticipated that the iris was pushed back and the angle opened after releasing the pupillary block but the anteriorly displaced ciliary process did not move back. Other similar studies confirmed this finding performed by Yoon et al. [11].

TCPD, as well as the iris thickness (ID1), is measured on the UBM at a point 500 µm from the scleral spur. TCPD constitutes the gap available for the iris between the trabecular meshwork and the ciliary process. An anteriorly placed ciliary process or a thick iris can reduce the peripheral ACD making it occludable. TCPD is represented as a continuum, with the highest values in the normal eyes, and the lowest values in the narrow form of ACG.

ILCD significantly increased after both procedures. This also agreed with by Caronia et al. [2] study which showed that flattening of the iris after LI for pupillary block increases iris-lens contact.

In concerning the efficacy of the IOP reduction by both procedures there was no significant difference in IOP reduction between the two groups. The efficacy of the IOP reduction by both procedures may depend upon the type of iris insertion.
Ultrasound Biomicroscopic Changes of the Angle after Laser Iridotomy

and the fragility of iris root not on the iris thickness [11]. Checking iris thickness according to iris insertion type of the angle-closure could not be performed due to the small number of subjects in the study group.

All the parameters had been compared between the LI and PT groups. There were no significant differences in the parameters before and after either procedure except for postoperative CPI ($p=0.019$) in the LI group, indicating that the degree of iris moving back was less in the PT group than in the LI group. However, measurement of CPI had not been checked according to the type of iris insertion or iris thickness that could affect CPI measurement and further study will be needed to determine the meaning of CPI measurement in both procedures.

In this study, the changes of the UBM parameters had been demonstrated after LI and PT, and these changes were similar after both procedures except CPI; the lens position and ciliary body were not significantly moved back, AOD was increased, and CPI was decreased after both procedures. It was evident that both the LI and PT procedures could improve the pressure gradient between the anterior and posterior chambers, but couldn’t improve the lens and ciliary body positions. This means that the potential risk of attack still remains unless the lens position is normalized.

UBM gives an accurate and objective documentation of the changes in anterior chamber angle morphology induced by an LPI and by trabeculectomy in PACG.

References


