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Original Article

Different energy densities of Nd:YAG laser iridotomy in treatment of angle-closure glaucoma

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Abstract: *Objective*: This study aimed to investigate the effect of Nd:YAG laser angle-closure glaucoma (AcG) incision on the surrounding membrane on corneal endothelial cells under different energy densities. *Methods*: Fifty-six AcG patients (73 eyes) in our department from June 2012 to June 2015 were enrolled. According to the percentile of total energy of Nd:YAG laser, the patients are divided into high energy (*n*=20), medium energy (*n*=17), and low energy (*n*=19) groups and are subjected to surrounding membrane incision. The difference in corneal endothelial cell damage among the three groups is compared before and after treatment. The correlation between Nd:YAG laser energy and cell density of 1 month post-operation was evaluated by Pearson correlation test. *Results*: The cell density, maximum and minimum cell area, average cell area and hexagonal cell percentage were not statistical different before and after treatment in low energy and median energy group (P>0.05). The cell density, coefficient variation and average cell area were significant increased after operation (P<0.05); However, the minimun cell area and hexagonal cell percentage were significant decreased after operation (P<0.05). No significant correlation between Nd:YAG laser energy and cell density was found in low and moderate energy group (P>0.05). However, significant negative correlation between Nd:YAG laser energy and cell density was found in the high energy group ($r_{pearson}$=0.42, P=0.03). *Conclusion*: Low- and medium-energy Nd:YAG laser membrane surrounding incision (MSI) does not exert any significant damage to corneal endothelial cells, and their outcomes are accurate and safe. However, high-energy Nd:YAG laser MSI, which has a total laser energy of over 45 mJ, significantly damages corneal endothelial cells.

Keywords: YAG laser, surrounding membrane incision, corneal endothelial cells

Introduction

Angle-closure glaucoma (AcG) is a common ophthalmology disease, and early treatment improves prognosis [1-3]. Nd:YAG laser is an effective method for treating AcG and has the advantages of short duration of action, strong penetrating power, low tissue thermal effect, and minimal thermal damage to surrounding tissues [4]. Nd:YAG laser is also effective in treating anatomical narrow-angle glaucoma caused by papillary block [5]. Nd:YAG iris laser can create holes in the surrounding membrane to release the pupil block, reduce the posterior chamber pressure, deepen the peripheral anterior chamber, and reopen the chamber angle, thus decreasing intraocular pressure and significantly reducing the probability of acute glaucoma attacks [6]. YAG iris laser surgery is currently widely used in clinical practice, but domestic and foreign scholars have not yet reached a consensus on whether YAG iridectomy can damage corneal endothelial cells [7, 8]. Moreover, insufficient studies are available about the damage of total energy from different lasers on corneal endothelial cells. Therefore, we conducted a retrospective analysis on 56 AcG patients (73 eyes) enrolled in our department for the past three years and measured the noncontact corneal endothelium count between preoperative and postoperative one week and postoperative one month to study the damage of different energies on corneal endothelial cells.

Methods

Clinical data

This study was conducted from June 2012 to June 2015. A total of 56 cases (73 eyes) of

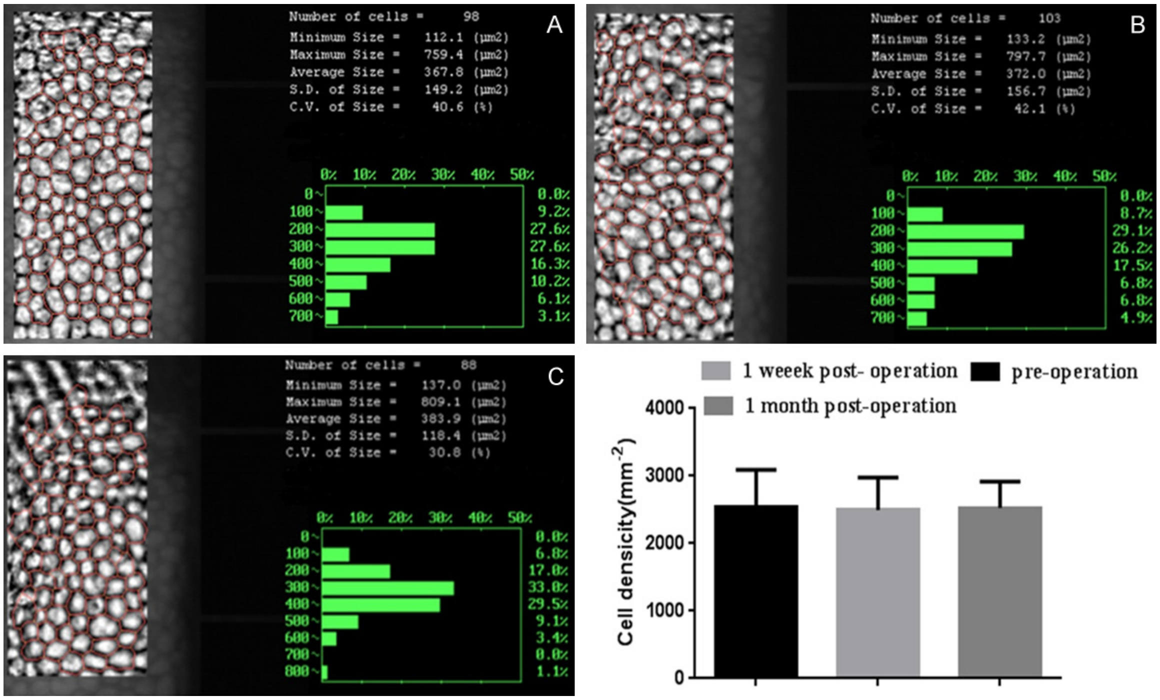

Figure 1. The cell density, coefficient variation, maximum and minimum cell area, average cell area and hexagonal cell percentage changes before and after operation in low energy group (A: 1-hour pre-operation; B: 1-week post-operation; C: 1-month post-operation).

Table 1. The changes of corneal endothelial cells (s) in the low energy group before and post-operation

Items	1-hour pre-operation	1-week post-operation	1-month post-operation
Cell density (mm^{-2})	2530.6±560.4	2497.3±481.2	2528.9±384.7
Coefficient variation (%)	32.34±2.1	33.12±3.3	33.28±2.6
Maximum cell area (μm^2)	720.3±357.6	718.9±340.5	717.5±361.2
Minimun cell area (μm^2)	183.5±53.7	178.1±46.3	181.3±58.2
Average cell area (μm^2)	426.0±168.3	437.1±171.8	425.5±175.3
Hexagonal cell (%)	61.1±14.7	60.7±12.3	60.4±13.5

Nd:YAG laser MSI, including 21 males (29 eyes) and 35 females (44 eyes) aged between 32 and 78 years (average: 45.2±14.7 years), were included in this study. A total of 41 eyes were in acute AcG preclinical phase or prodromal stage, 24 cases were in remission, and 8 were in chronic phase. The low-energy group comprised 20 cases, the medium-energy group comprised 17 cases, and the high-energy group comprised 19 cases.

Instruments

Swiss HAAG-STREIT Q-schwind YAG laser treatment instrument was used to incise the surrounding membrane, and corneal endothelial cells were measured using noncontact corneal endothelium microscopy (Topcon SP-3000P). The central area of the cornea was selected as a unified measurement area, and the intelligent analysis system on the instrument was used to screen the cell measurement indicators with clear images.

Operation procedure

MSI surgery was performed by a skilled ophthalmologist; intraoperative single-laser energy was controlled between 1.0 and 5.0 mJ to avoid a high single energy. The total energy of the laser used in the MSI was recorded, and the MSI laser energy value was calculated based on the percentile, such as P33 and P66 corresponding to 30 and 45 mJ, respectively. The laser energy was divided into the following categories according to energy values: low-energy group at 0-20.0 mJ; medium-energy group at 21.0-45.0 mJ; and high-energy group at 46.0-60.0 mJ. One hour before surgery, 1% pilocarpine eye drops for *papillary contraction* and 0.5% ciprofloxacin for topical anesthesia were

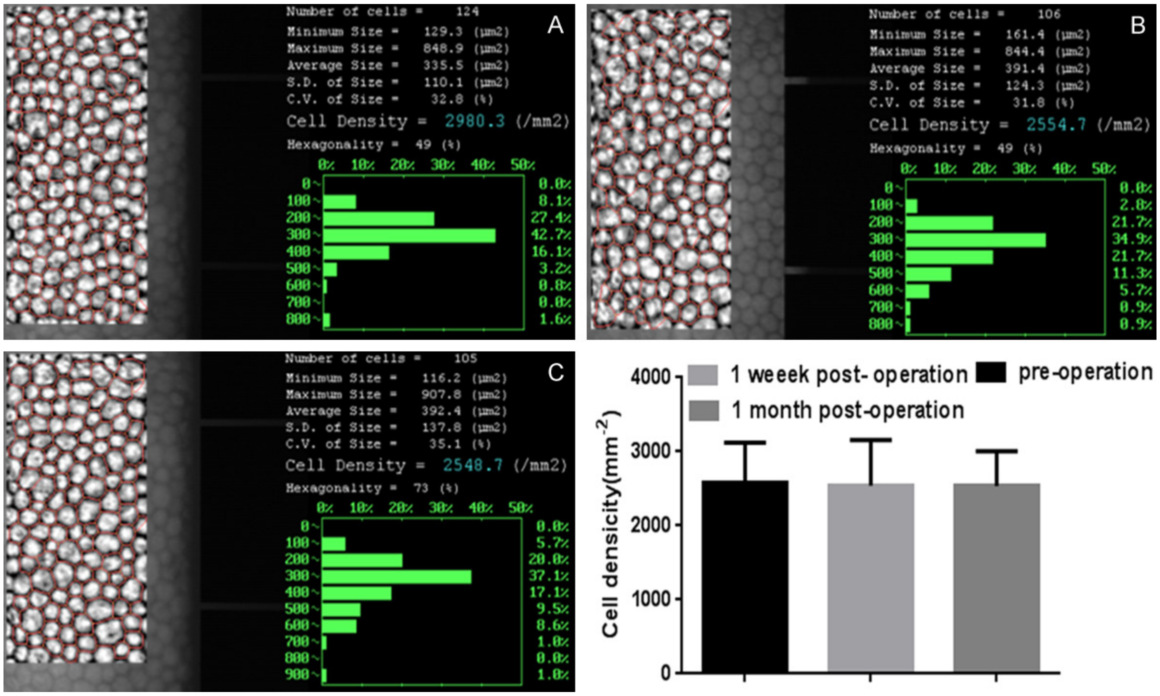

Figure 2. The cell density, coefficient variation, maximum and minimum cell area, average cell area and hexagonal cell percentage changes before and after operation in median energy group (A: 1-hour pre-operation; B: 1-week post-operation; C: 1-month post-operation).

Table 2. The changes of corneal endothelial cells (s) in the median energy group before and post-operation

Items	1-hour pre-operation	1-week post-operation	1-month post-operation
Cell density (mm^{-2})	2579.6±540.7	2542.7±613.0	2539.2±465.2
Coefficient variation (%)	31.14±6.9	30.52±7.1	31.5±4.8
Maximum cell area (μm^2)	931.2±428.7	904.2±494.2	952.9±553.2
Minimun cell area (μm^2)	188.4±70.0	198.5±115.9	200.2±131.5
Average cell area (μm^2)	511.0±138.3	515.9±167.7	505.0±165.8
Hexagonal cell (%)	60.1±11.4	57.8±13.4	56.1±8.6

administered. First, a small amount of ointment was applied to the surface of the Abraham lens (AL), and the laser hole was preferentially placed above the temporal or nasal fossa and focused on the thinnest part. When no hidden risks exist, the area where iris texture is loose and iris fissure or chamber angle is wide was selected. When the initial laser energy was 1.0-2.5 mJ, it was reduced after iris penetration to ensure a clean incision. The following intraoperative characteristics suggest that the incision has penetrated the iris: (1) mushroom cloud sign of anterior chamber, (2) positive return of aqueous humor, (3) deepening of anterior chamber, and (4) orange fundus reflex at the laser aperture under the slit lamp. The laser aperture can be enlarged to 0.5-1.0 mm. Routine nonsteroidal anti-inflammatory treatment was carried out after operation, and the monitoring result of intraocular pressure was normal. Qualitative and quantitative observations of corneal endothelial cells were performed with AL before operation and one week and one month after operation. Each patient was tested thrice by the same operator, and the average measured values, namely, average cell area (AVE), maximal cell area (MAX), minimum cell area (MIN), cell density (CD), coefficient of variation (CV), and standard deviation of cell area (SD) ($P<0.05$), of the central corneal endothelium of the pupil were recorded. The instrument was calibrated and standardized before measurement to ensure the stability and accuracy of the machine.

Statistical analysis

The statistical analysis was made with STATA11.0 statistical software (http://www.stata.com), the measurement data were expressed with mean ± standard deviation and

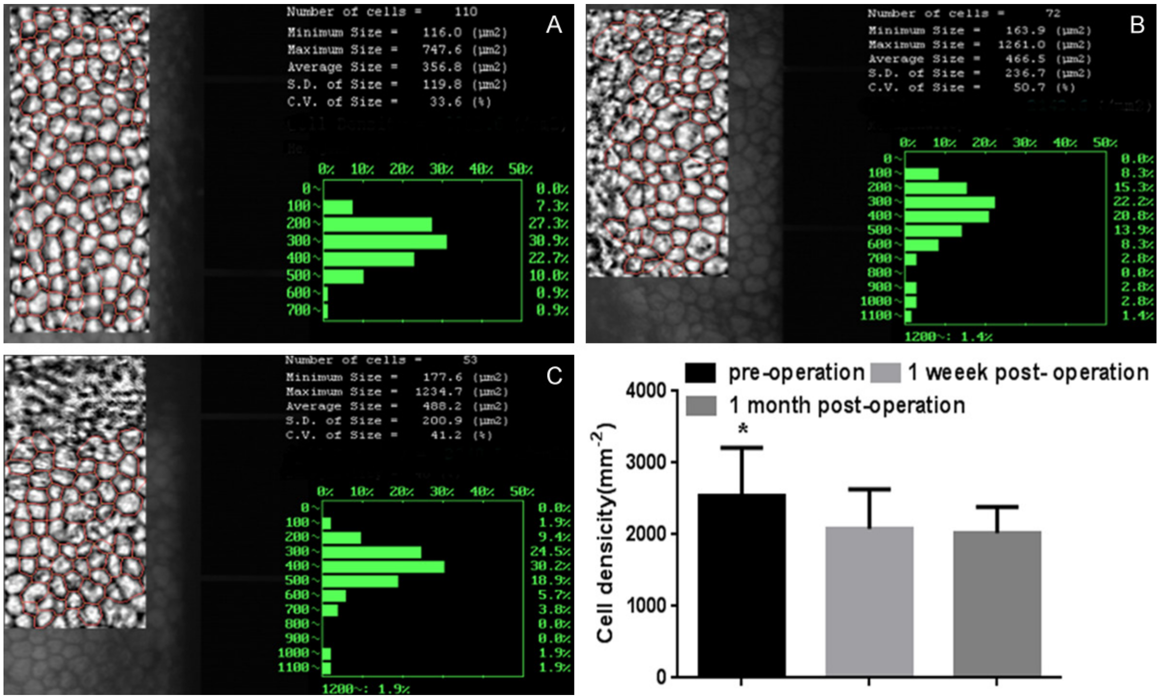

Figure 3. The cell density, coefficient variation, maximum and minimum cell area, average cell area and hexagonal cell percentage changes before and after operation in high energy group (A: 1-hour pre-operation; B: 1-week post-operation; C: 1-month post-operation).

Table 3. The changes of corneal endothelial cells (s) in the high energy group before and post-operation

Items	1-hour pre-operation	1-week post-operation	1-month post-operation
Cell density (mm^{-2})	2535.2±675.3	2082.5±549.6*	2020.4±365.4*
Coefficient variation (%)	32.34±2.1	41.52±4.6*	42.78±3.7*
Maximum cell area (μm^2)	693.3±334.1	670.6±305.3	672.4±383.2
Minimun cell area (μm^2)	169.5±84.9	132.2±79.3*	136.5±100.3*
Average cell area (μm^2)	390.0±128.6	437.5±153.9*	441.7±147.8*
Hexagonal cell (%)	58.8±13.8	47±11.0*	46.3±17.5*

*P<0.05, compared to 1-hour pre-operation.

the comparison among groups was made based on the F-test of the sample mean. The enumeration data were expressed with a relative number, and the comparison between groups was made based on *Chi*-square test. The related data were based on the Pearson correlation test. P<0.05 meant a statistical difference.

Results

Low energy group

In the low energy group, YAG laser energy was controlled at 0-20 mJ. The cell density, maximum and minimum cell area, average cell area and hexagonal cell percentage were not statistical different before and after treatment. (**Figure 1**; **Table 1**).

Medium energy group

In the median energy group, YAG laser energy was controlled at 21~45 mJ. The cell density, maximum and minimum cell area, average cell area and hexagonal cell percentage were not statistical different before and after treatment. (**Figure 2**; **Table 2**).

High energy group

In the high energy group, YAG laser energy was controlled at 46~605 mJ. The cell density, coefficient variation and average cell area were significant increased after operation (P<0.05); However, the minimun cell area and hexagonal cell percentage were significant decreased after operation (P<0.05), (**Figure 3**; **Table 3**).

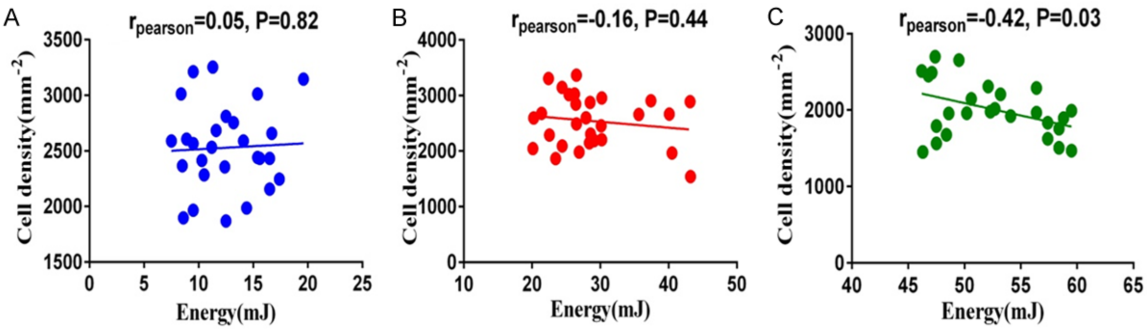

Figure 4. Correlation between Nd:YAG laser energy and cell density (A: Low energy group; B: Median energy group; C: High energy group).

Correlation between Nd:YAG laser energy and cell density

The correlation between Nd:YAG laser energy and cell density of 1 month post-operation was evaluated by Pearson correlation test. No significant correlation between Nd:YAG laser energy and cell density was found in low and moderate energy group (P>0.05). However, significant negative correlation between Nd:YAG laser energy and cell density was found in the high energy group ($r_{pearson}$=0.42, P=0.03), (**Figure 4**).

Discussion

Normal cornea in the relative dehydration state is the key factor to maintain light transmission, but the density of corneal endothelial cells gradually decreases with age, and its transmittance begins to decline [9, 10]. Damage to endothelial cells can decrease the barrier function of corneal epithelial cells. CD values less than 500/mm^2 indicate that the compensatory function does not work completely [11, 12].

Nd:YAG laser is an infrared light that produces ionization effect after acting on the target tissues [8, 13]. With rapid plasma expansion, shock waves, which can cut the target tissue without heat and coagulation, are generated. Many reports have indicated that laser treatment damages corneal endothelial cells [14]. In addition, laser-induced damage to corneal endothelial cells is caused by the following reasons: local radiation effect of laser, damage from shock waves and sound effects caused by laser to corneal endothelial cells, and direct damage of pigment and debris on the iris to the local corneal endothelium. These damages positively correlate with the use of laser energy. However, some scholars believe that MSI surgery is safer than other laser treatments and does not cause a substantial damage to corneal endothelial cells [15]. Chen *et al.* [16] believe that the farther distance between corneal endothelium and laser focus is safer, with 1.0 mm being the average safe distance. The laser should be positioned in the anterior chamber angle, which should be stretched as wide as possible, for patients whose anterior chamber is very shallow or surrounding anterior chamber is basically disappearing. The surgeon uses corneal contact lens to deepen the local anterior chamber, thus reducing direct damage to corneal endothelial cells caused by a short distance between the laser focus and the corneal endothelium.

In this study, the damage caused by Nd:YAG laser to corneal endothelial cells between the low- and medium-energy groups was not statistically different during AcG treatment. However, when the total laser energy exceeded 45 mJ, the local radiation and blasting effects of the laser may significantly damage the corneal endothelial cells. This study also conducted a comparative analysis on the data of the high-energy treatment group, and the results indicated that the damage of corneal endothelial cells increased with increasing total laser energy [17, 18].

The results of this study imply that high-energy laser damages the corneal endothelial cells; thus, the total laser energy should be reduced when penetrating the iris. In clinical practice, iris penetration can be performed several times in patients in whom one-time penetration is difficult to avoid or reduce the damage to corneal endothelium and improve the safety of YAG laser incision on the surrounding membrane.

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Disclosure of conflict of interest

None.

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