

## **Comparison of Changes in Intraocular Pressure and Anterior Chamber Before and After Cataract Surgery**

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### **ABSTRACT**

Cataract is the leading cause of blindness worldwide. Fortunately, cataract-induced blindness is reversible by cataract surgery. In addition to reclaiming lost vision, cataract surgery lowers intraocular pressure, but the reason for this remains unclear. Understanding the mechanism behind intraocular pressure reduction following cataract surgery has implication for treating glaucoma, which involves lowering intraocular pressure through glaucoma medications or surgeries. Adequate control of intraocular pressure through cataract surgery would render glaucoma treatment nonessential and could become an optimal solution for patients with co-existing cataract and glaucoma. To answer the research question of whether anterior chamber angle alteration induces intraocular pressure reduction, we compared changes in intraocular pressure and anterior angle before and after cataract surgery. Age, ethnicity, and gender are risk factors related to cataract development, but their effects on the degree of changes in intraocular pressure and anterior chamber angle following cataract surgery are unclear. The degree of change in intraocular pressure and anterior chamber angle following cataract surgery is evaluated in terms of these risk factors, to assess whether a relationship exist between them. Statistical analysis revealed a significant decrease in intraocular pressure and an increase in anterior chamber angle opening distance following cataract surgery. However, comparison of the degree of changes in intraocular pressure and angle opening distance in terms of age, ethnicity, and gender revealed insignificant difference within each group. In conclusion, we found that anterior chamber angle extension is a mechanism for intraocular pressure reduction following cataract surgery and this is consistent regardless of age, gender, and ethnicity. Repeated studies with this experimental design at other clinical sites are needed to substantiate the applicability of our findings to the general population.

### **KEYWORDS**

Phacoemulsification, Glaucoma, Visual Acuity, Age, Ethnicity, Gender

## INTRODUCTION

Cataract causes about 70% of blindness globally and is projected to account for vision impairment in more than 75 million people by 2020, but fortunately cataract-induced blindness is reversible by surgical intervention (Roodhooft 2002; Allen 2006). A cataract is any discoloration of the human lens that reduces its transparency and lowers light transmission through the eye (Bradford 1998). Left untreated, a cataract grows and progressively reduces vision until blindness occurs (Allen 2006). Surgery is needed to reclaim vision lost to cataract. In phacoemulsification, the most common surgical technique used in the developed world to address cataract, a surgeon makes a small incision through the cornea to expose the lens to a probe that emits ultrasound waves to break the lens into small pieces, which are suctioned out and replaced with an artificial lens (Bournias 2005).

Cataract surgery has the beneficial side effect of intraocular pressure reduction, but the reason for this remains unclear (Issa *et al.* 2005). Noting a decrease in the outflow facility's resistance to the aqueous humor flow after surgery, Meyer proposed that an improvement in the aqueous outflow facility of the eye leads to intraocular pressure reduction (Meyer *et al.* 1997). Resistance to the flow of aqueous humor elevates intraocular pressure in the eye (Bournias 2005). So a decrease in the outflow facility's resistance should subsequently lead to lower intraocular pressure. Excluding Meyer's work, no studies provide evidence for possible mechanisms behind reduction in intraocular pressure after cataract surgery.

Identifying possible mechanisms for reduced intraocular pressure after cataract surgery has implications in the field of ophthalmology. Intraocular pressure is associated with glaucoma, the second leading cause of blindness in the world, which is projected to affect more than 60 million people by 2010 (Quigley and Broman 2006). Glaucoma treatment involves lowering intraocular pressure through medication or surgery (Bournias 2005). Better understanding of the mechanism behind intraocular pressure reduction after cataract surgeries may allow for adequate control of intraocular pressure through the phacoemulsification, which would render anti-glaucoma medications and surgeries nonessential to the treatment of glaucoma. This will eliminate the patient's risk of side effects from anti-glaucoma medication or potential complications from glaucoma surgery. Furthermore, because some risk is associated with all surgical interventions, cataract surgery is currently only considered when the prospects for recovery of vision outweigh any possible surgical complications (Kim and Choi 2008). But if cataract surgery succeeds in

adequately controlling intraocular pressure, this could lead to reformation of clinical guidelines, in which the prerequisites for cataract surgeries could be lowered for patients with co-existing cataract and glaucoma, as cataract surgery would be an optimal solution for such patients.

Variation in the eye's anterior chamber angle affects intraocular pressure (Bournias 2005). The anterior chamber houses the ciliary body, which produces aqueous humor, a watery fluid that circulates through the pupil, trabecular meshwork, Schlemm's canal, and uveoscleral outflow facility. Resistance to the flow of aqueous humor anywhere along this pathway causes a rise in intraocular pressure. If the anterior chamber has a wide outflow angle, the aqueous humor is stored in a voluminous compartment with a spacious outlet, allowing for great ease of flow. But if the anterior chamber has a narrow outflow angle, the aqueous humor is confined in a small space with a tiny exit channel, resulting in more constricted flow (Bradford 1998).

Intrinsic factors, including age, ethnicity, and gender are associated with cataract development, but it is unclear if they affect the degree of changes in intraocular pressure and anterior chamber parameters after cataract surgery (Bradford 1998). The human lens grows throughout a person's life by producing new cortical lens fibers. As new lens fibers are produced and the old ones are not removed, lens fibers accumulate and appear as pigmentation within the lens that reduces light transmission (Allen 2006). Because lens fibers build up over a long period, cataract usually occurs in the elderly. Cataract is significantly more common among females than males and more prevalent in Hispanic and African Americans than in Caucasian Americans (Congdon *et al.* 2004).

In order to determine whether anterior chamber changes are a mechanism behind intraocular pressure reduction following cataract surgery, I will compare changes in intraocular pressure and anterior chamber angle before and after cataract surgeries. I hypothesize that anterior chamber angle will increase after cataract surgery, and that the change in anterior chamber angle is a mechanism behind the reduction of intraocular pressure. I will then evaluate the degree of change in intraocular pressure and anterior chamber angle in terms of age, ethnicity, and gender. I hypothesize that there is a correlation between the intrinsic factors described above and the amount of changes in intraocular pressure and anterior chamber angle.

My alternative hypothesis is that the anterior chamber angle will experience a decrease after cataract surgery, establishing this change as the mechanism behind the reduction of intraocular pressure. Another alternative hypothesis is that anterior chamber angle will not change, and thus

can be ruled out as a possible mechanism behind the reduction of intraocular pressure following cataract surgery. The alternative to the second hypothesis is that there are no correlations between the intrinsic factors and the amount of changes in intraocular pressure and anterior chamber angle.

## **METHODS**

This research project was conducted at the Beckman Vision Center, located at the University of California, San Francisco School of Medicine. The subjects studied were cataract patients enlisted by Dr. Shan Lin, Associate Professor of Clinical Ophthalmology at the University of California at San Francisco. Eligibility criteria for participation required that patients have vision-threatening cataract and were already following up regularly at Dr. Lin's outpatient clinic. This was to increase the likelihood that the study population would return for check-ups. Dr. Shan Lin schedules and performs phacoemulsification on patients to treat cataract as soon as they agree to participate in the study.

Patients had their anterior chamber angle and intraocular pressure examined prior to cataract surgery. We used an Anterior Segment Optical Coherence Tomography, a device that emits infrared light to obtain cross-sectional imaging of the eye (Radhakrishnan 2001), to measure anterior chamber angle. We used the Goldmann Applanation Tonometer to measure intraocular pressure. With this device, the physician applies anesthetic drops to the eye and then presses the tip of the tonometer against the cornea. The intraocular pressure is then determined by measuring the amount of aqueous humor displaced by the tonometer (Bournias 2005). The values of the intraocular pressure and anterior chamber parameters measurements can vary depending on the measuring instrument and the person performing the examination. To ensure reliability and consistency in the intraocular pressure and anterior chamber parameters measurements, the same measuring devices were used throughout the study, and Dr. Shan Lin performed all measurements. Both examinations were repeated one month after cataract surgery. Measurements from these examinations were recorded and changes in intraocular pressure and the anterior chamber angle were compared between pre-operation and post-operation. Data on age, ethnicity, and gender were then collected from the patients' medical charts. The degree of changes in intraocular pressure and anterior chamber angle were evaluated in terms of these variables to see whether a correlation exists or not.

**RESULTS**

We examined the eyes of 68 patients, comparing pre-operation and post-operation visual acuity, intraocular pressure, and angle opening distance across ethnicity, gender, and age (Table 1) to identify any significant change brought about by cataract surgeries. Depending on whether the pre-operation and post-operation intrinsic factors came from a normally distributed population, as determined by the Shapiro-Wilk test (Table 2), we used different statistical tests to analyze the significance of the change between the pre-operation and post-operation data. If the pre-operation and post-operation data came from a normally distributed population, we used a t-test for this analysis. If the data did not come from a normally distributed population, we used Friedman Rank Sum test for this analysis.

**Table 1. Demographic characteristics of study population.**

Total number of patients	Age Range	Gender	Ethnicity
68	90-99: 7 80-89: 27 70-79: 24 60-69: 10	female: 38 male: 30	Asian American: 33 African American: 11 Hispanic American: 8 Caucasian American: 16

**Table 2. Results of Shapiro-Wilk test on pre-operation and post-operation visual acuity, intraocular pressure, and angle opening.**

Intrinsic factors	P-value	Distribution
Pre-operation VA	7.176e-13	Non-normal
Post-operation VA	5.204e-13	Non-normal
Pre-operation IOP	9.378e-3	Non-normal
Post-operation IOP	3.095e-2	Non-normal
Pre-operation AOD	4.519e-2	Non-normal
Post-operation AOD	5.289e-2	Non-normal

After evaluating the significance of the changes between the pre-operation and post-operation visual acuity, intraocular pressure, and angle opening distance, we used the Shapiro-Wilk test again to assess the normality in the differences between pre-operation and post-operation data (Table 3). If they had a normal distribution, we then evaluated them in terms of gender, ethnicity, and age using an Anova test. If they did not have a normal distribution, we evaluated them in terms of gender, ethnicity, and age using the Kruskal-Wallis test.

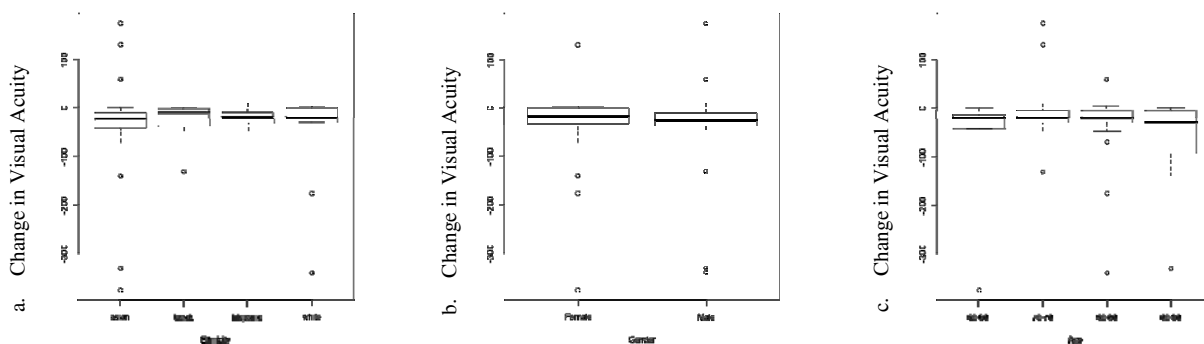
**Table3. Results of Shapiro-Wilk test on differences between pre-operation and post-operation visual acuity, intraocular pressure, and angle opening.**

Intrinsic factors	P-value	Distribution
Change in visual acuity	4.694e-11	Non-normal
Change in intraocular pressure	0.5588	Normal
Change in angle opening distance	4.402e-05	Non-normal

Comparison of data before and after cataract surgeries for both eyes revealed a decrease in visual acuity (Table 4), signifying vision improvement for the study population. While a person with normal vision has a visual acuity of 20, the study population began with an average visual acuity of 76.68. Following cataract surgery, the average visual acuity became 45.91. The Friedman Rank Sum test confirmed that this difference is significant with a p-value of 5.733e-09. Comparison of data before and after cataract surgeries in terms of ethnicity, gender, and age showed that the four racial groups, both men and women, and the four different age groups experienced visual acuity reduction. However, the Kruskal-Wallis test showed there was no significant difference in visual acuity within each group (Fig. 1).

**Table 4: Summary of pre-operation and post-operation measurements for visual acuity, intraocular pressure, and angle opening distance**

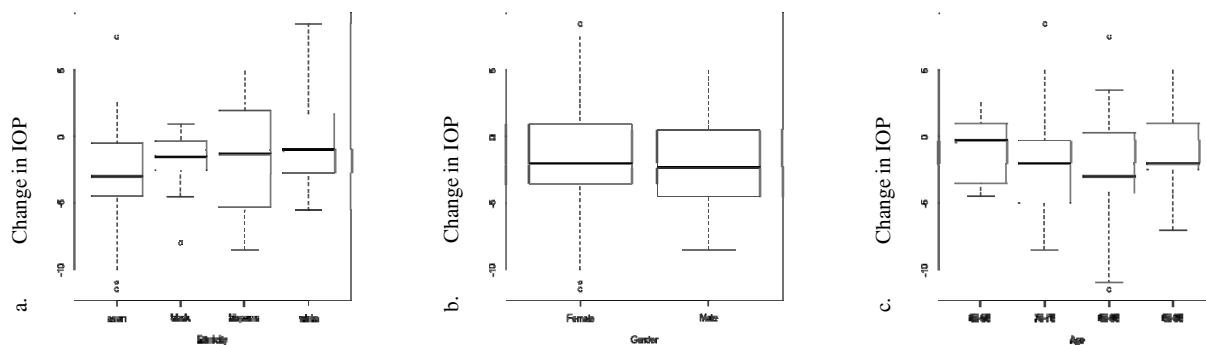
Category	Mean	Standard Deviation
Pre-Operation VA	76.68	83.73
Post-Operation VA	45.91	42.42
Change in VA	-34.75	85.17
Pre-Operation IOP	15.08	3.71
Post-Operation IOP	13.07	3.68
Change in IOP	-2.01	3.96
Pre-Operation AOD	0.34	0.17
Post-Operation AOD	0.50	0.21
Change in AOD	0.09	0.18



**Figure 1. Results of Kruskal-Wallis test on differences between pre-operation and post-operation visual acuity in terms of ethnicity, gender and age.**

- Differences between pre-operation and post-operation VA in terms of ethnicity: p-value = 0.774
- Differences between pre-operation and post-operation VA in terms of gender: p-value = 0.774
- Differences between pre-operation and post-operation VA in terms of age: p-value = 0.7679

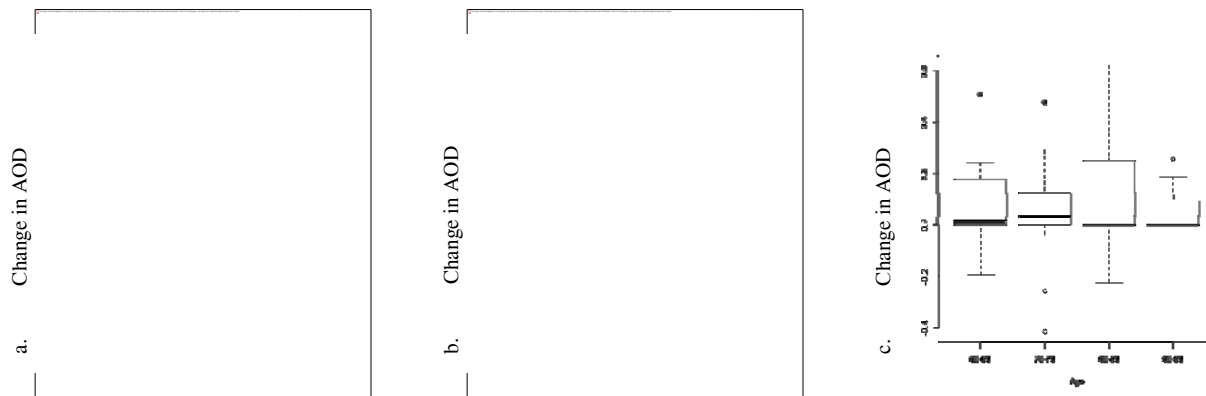
Comparison of intraocular pressure before and after cataract surgeries for both eyes (Table 4) revealed that the study population's pre-operational average intraocular pressure of 15.08 mmHg was reduced to an average of 13.07mmHg following cataract surgery. The Friedman Rank Sum test confirms that this difference is significant with a p-value of 0.002616. Comparison of intraocular pressure before and after cataract surgeries in terms of ethnicity, gender, and age showed that the four racial groups, both men and women, and the four age groups experienced intraocular pressure reduction. Again, the Kruskal-Wallis and Anova tests show that there is no significant difference in intraocular pressure within each group(Fig. 2).

**Figure 2. Results of Kruskal-Wallis test and Anova test on differences between pre-operation and post-operation intraocular pressure in terms of ethnicity, gender and age.**

- Differences between pre-operation and post-operation IOP in terms of ethnicity: p-value = 0.097
- Differences between pre-operation and post-operation IOP in terms of gender: p-value = 0.989
- Differences between pre-operation and post-operation IOP in terms of age: p-value = 0.594

Comparison of anterior chamber angle opening distance before and after cataract surgeries for both eyes (Fig. 2) showed that the study population had an average anterior chamber angle opening distance of 340 micrometers before surgery and an average anterior chamber angle opening distance of 500 micrometers after surgery. The Friedman Rank Sum test confirmed that this difference was significant with a p-value of 6.249e-05. Comparison of anterior chamber angle opening distance before and after cataract surgeries in terms of ethnicity, gender, and age showed that all four racial groups, both men and women, and the four different age groups

experienced an increase in anterior chamber angle opening distance. The Kruskal-Wallis test showed there was no significant difference in angle opening distance within each group (Fig. 3).



**Figure 3. Results of Kruskal-Wallis test on differences between pre-operation and post-operation angle opening distance (AOD) in terms of ethnicity, gender and age.**

- a. Differences between pre-operation and post-operation AOD in terms of ethnicity: p-value = 0.280
- b. Differences between pre-operation and post-operation AOD in terms of gender: p-value = 0.666
- c. Differences between pre-operation and post-operation AOD in terms of age: p-value = 0.797

## DISCUSSION

The results of this study confirmed my hypothesis that an increase anterior chamber angle is a mechanism for intraocular pressure reduction following cataract surgery. The increase in angle opening distance following cataract surgery is significant, suggesting that cataract surgery widens the anterior chamber angle. Resistance to the flow of aqueous humor, which occurs when obstructions in the flow path hinder the efficient circulation of aqueous humor, is responsible for the rise in intraocular pressure in the eye and resistance. An increase in the anterior chamber angle may explain decreasing intraocular pressure following cataract surgery, because a wider anterior chamber angle should provide a less obstructed flow path, allowing more room for the aqueous humor to flow. Evaluation of the increment in anterior chamber angle opening distance following cataract surgery in terms of ethnicity, gender, and age showed that variation within the group is insignificant. This suggests that ethnicity, gender, and age do not affect the degree of widening of the anterior chamber angle.

Comparison of pre-operation and post-operation visual acuity confirmed previous findings (Roodhooft 2002; Allen 2006) that vision loss due to cataract can be recovered through surgical intervention, by showing significant reduction in visual acuity following cataract surgery.

Evaluation of visual acuity reduction following cataract surgery in terms age, gender, and ethnicity, however, showed that variation in the amount of visual acuity decreased within each group is insignificant. This suggests that surgical intervention for cataract is an effective way of reclaiming loss vision regardless of the person's age, gender, and ethnicity.

The second hypothesis, that age, gender, and ethnicity play a role in affecting the amount of changes in anterior chamber angle, visual acuity, and intraocular pressure following cataract surgery, was completely rejected when the variation in intraocular pressure reduction was also insignificant in all three groups. It is important to note, however, that there was a significant difference between the pre-operation intraocular pressure and post-operation intraocular pressure. This is because, although cataract surgery is an effective method of vision recovery, it usually is not the first course of action in treating a cataractous patient. When contemplating the treatment options for a patient, physicians tend to recommend a less invasive form of treatment, such as oral or topical medications, due to potential surgical complications. Since intraocular pressure reduction is the main form of treatment for glaucoma, adequate control of intraocular pressure by means of surgery could provide doctors with sufficient incentive to prioritize cataract surgery for patients with co-existing cataract glaucoma.

The Collaborative Normal-Tension Glaucoma Study Group (1998) found that normal-tension glaucoma progression can be halted if intraocular pressure is reduced by 30% or more. Our study population had a pre-operation intraocular pressure average of 15.08 mmHg and an average of 13.07 mmHg after cataract surgery. This is a 13% reduction, which means it is not sufficient enough to stop glaucoma progression. Although this study points out that the current method for cataract surgery cannot stop glaucoma development reliably, the confirmation of the first hypothesis illuminates the direction for researchers seeking ways to adequately control intraocular pressure. Successful discovery of a modification to the current form of cataract surgery that would allow for adequate intraocular pressure reduce could solidify the incentive for physicians to prioritize cataract surgery for patients with co-existing cataract glaucoma. Increase in anterior chamber angle causes intraocular pressure reduction following cataract surgery, so future research should seek ways to make adjustments during the surgical procedures in order to make the angle opening distance increment as large as possible. For example, because human lens thickness correlates negatively to the anterior chamber angle opening and an increase in lens thickness decreases anterior chamber angle width (Memarzadeh *et al.* 2007), engineering a

thinner artificial lens for cataract surgery may widen anterior chamber angle sufficiently to reduce intraocular pressure to effectively treat glaucoma.

Rejection of the second hypothesis has implications bearing on racial and gender inequalities in eye care service access. Wang *et al.* (1997) found that African Americans who received Medicare were only 67% as likely as Caucasian American beneficiaries to receive eye care services. Since this study has shown that racial characteristics do not affect the degree of change in visual acuity, intraocular pressure, or angle opening distances following cataract surgery, thereby demonstrating equivalent benefit reaped from cataract surgery regardless of ethnicity, the lower number of cataract surgeries offered to the non-white population is not justified. Lewallen *et al.* (2009) also found that in low- to mid-income countries, males are given significantly more cataract surgical insurance coverage than females. The present study revealed that male and female receive equal improvement from cataract surgery. Thus, the lower level of surgical insurance coverage for females is not associated with different levels of benefits provided by the surgery, which means this unequal treatment is again not justified.

Aside from the issue of eye care service inequality, rejection of the second hypothesis has implication in terms of promoting cataract surgeries for the elderly. Harwood *et al* (2005) found that cataract surgery decreases rate of falling and improves general health status for elderly women. So, when eye care services offer cataract surgeries to elderly women, they should not target those of a certain age because all age ranges receive similar benefits from cataract surgery.

This study shows that an increase in anterior chamber angle is the mechanism behind intraocular pressure reduction following cataract surgery. But this study does not address whether increased in anterior chamber angle allows more efficient flow of aqueous humor. Although an increase in the anterior chamber angle is a reasonable mechanism for decreasing intraocular pressure because a wider anterior chamber angle would provide more room for the aqueous humor to flow, further study examining the aqueous humor flow rate difference before and after cataract surgery is needed to confirm the validity of this rationale. Another shortfall of this study was the small sample size of the study population, which potentially allowed outliers to skew the results. Future studies can repeat this experimental design with a larger sample size to confirm the validity of our findings.

In addition to discovering the mechanism behind intraocular pressure following cataract surgery, evaluating the degree of changes in intraocular pressure and anterior chamber angle in terms of

ethnicity, gender, and age reveals that none of these factors are relevant in affecting decisions about who should receive cataract surgery. Since these three demographic characteristics do not affect the benefits received from cataract surgeries, any discrepancies between the general population and the cataract treatment population in terms of age, gender, and ethnicity constitute a healthcare inequality and should be addressed in future health care policies.

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