




# Changes in intraocular pressure control in the first year after secondary intraocular lens implantation in children

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## Abstract

**Purpose** To compare intraocular pressure (IOP) control before and during the first year after secondary intraocular lens (IOL) implantation in children.

**Methods** This was a retrospective chart review of children who received secondary IOL implantation. We analyzed IOP and antiglaucoma medications before and after implantation. The latest exam with IOP measurement found within the 2–15 month period after IOL implantation was used for the postoperative data. Failure to maintain IOP control was defined as either the addition of antiglaucoma medication(s) or a rise in IOP > 4 mm Hg. Statistical analyses were performed to assess risk factors for failure to control IOP after surgery, namely age at IOL implantation, preoperative glaucoma status, and IOL fixation location.

**Results** A total of 100 eyes were included. The mean duration of follow-up was 7.74 months (SD = 3.11). Twenty-three of one hundred eyes failed to maintain IOP control according to our definition. Eyes with a history of having had a traumatic cataract ( $n = 3$ ) had a more than threefold increased risk of failure ( $P = 0.015$ ). Although not statistically significant, very young age at initial cataract surgery (<2 months old) had a twofold increased risk of failure compared to an older age (>12 months old) ( $P = 0.213$ ). No other risk factors were found to have statistical significance.

**Conclusion** Secondary IOL implantation carries a modest risk of worsening IOP control in the first year after implantation, for which, a history of ocular trauma or young age at initial cataract surgery seems to present the highest risk.

## Introduction

For children who have undergone cataract surgery, glaucoma is one of the most concerning complications. The prevalence reported in the literature varies and appears to increase over time after cataract surgery [1, 2]. Furthermore, it has been reported that the vast majority of cases of glaucoma after cataract surgery are found in children who had cataract surgery at a very young age [3–5]. Other risk factors for glaucoma, such as microcornea, have been investigated [6], and hypotheses related to the possible

protective effects of intraocular lens (IOL) implantation have even been proposed [7]. Subsequently, Trivedi et al. reported no difference in rates of glaucoma between primary IOL implantation and primary aphakia [3]. The Infant Aphakia Treatment Study investigators have also reported that there was no significant difference in the rates of glaucoma or glaucoma-suspect incidence between the primary IOL implantation group and the primary aphakia group at 5 years after cataract removal [5]. The British Congenital Cataract Interest Group recently reported glaucoma after cataract surgery in a cohort of 235 children who had cataract surgery before 2 years of age: “by 5 years after primary cataract surgery, 20% of children with bilateral cataract, and 12% of children with unilateral had developed secondary glaucoma,” but following adjustment for age at surgery and axial length, IOL implantation was not associated with the risk of glaucoma [8].

The onset or worsening of glaucoma following secondary IOL implantation is of further concern for many surgeons. This study focuses on IOP control after IOL

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implantation. Intraocular pressure has traditionally been used as a surrogate endpoint for glaucoma treatment in clinic research, although clinical management of glaucoma involves a more complex array of data (e.g., optic nerve examination, visual field testing). Our primary goal was to compare IOP control before and after secondary IOL implantation in children during the first year after IOL surgery.

## Methods

This retrospective interventional consecutive case series reviewed the charts of all patients who had cataract surgery without IOL implantation before 18 years of age and received secondary IOL implantation at the Storm Eye Institute, Medical University of South Carolina (MUSC) between 2000 and 2018. The study was approved by the MUSC Institutional Review Board for human research. We analyzed IOP and antiglaucoma medications preoperatively and 2–15 months after secondary IOL implantation. For the postoperative data, we used the latest exam with IOP measurement found within the follow-up period. We gathered other data related to demographics, intraoperative and postoperative complications, age at initial cataract extraction, and IOL fixation location. Secondary analyses were conducted to investigate risk factors for worsening IOP control. Intraocular pressure was measured by rebound tonometry (iCare, Tiolat Oy, Helsinki, Finland) or applanation tonometry (Tono-pen XL, Medtronic Solan, Jacksonville, FL).

Eyes were excluded if there was not at least one preoperative and postoperative IOP measurement with accompanying antiglaucoma medication data between 2 and 15 months after secondary IOL implantation. Eyes were also excluded if any concurrent procedures were performed at the time of the secondary IOL implantation (e.g., glaucoma procedure). All available IOP measurements were recorded, but a single preoperative IOP and postoperative IOP were used for the data analysis. When selecting the IOP to be used for data analysis, we used the latest preoperative IOP (i.e., closest to the surgery) and the latest postoperative IOP in the follow-up period (2–15 months after surgery). The only exception to this rule is if there was a clear note in the chart that the IOP was unreliable (e.g., the child was crying or squeezing).

Failure to maintain IOP control during this postoperative period was defined as either the addition of antiglaucoma medication(s) or a rise in IOP > 4 mm Hg.

Any change (higher or lower) in the number of antiglaucoma medications and the IOP value postoperatively was documented. All outcomes were evaluated using a generalized estimating equation (GEE) approach. The GEE

models for failure to control IOP assumed a binomial distribution with a log link. The GEE models for change in medication and IOP assumed a normal distribution with an identity link. All GEE models included a random effect to account for correlation between measures collected within patients for patients that had secondary IOL implantation in both eyes. Model assumptions were checked graphically, and transformations were considered when necessary. All analyses were conducted in SAS v. 9.4 (SAS Institute, Cary, NC).

## Results

A total of 100 eyes of 63 patients underwent secondary IOL implantation during the study period and met the criteria to be included in the study. Demographic data are listed in Table 1. IOP and antiglaucoma medication results are listed in Table 2.

Of the 100 eyes, 23 (23.0%) failed to maintain IOP control. Risk factors for failure are listed in Table 3. Age at initial cataract surgery was investigated as a risk factor for failure to maintain IOP control. Age at initial cataract surgery data was not available for nine eyes, which were operated elsewhere for cataract surgery (secondary IOL implantation was done at our institute). The cohort was divided into three groups based on age at initial cataract surgery: <2 months old ( $n = 33$ ), 2–12 months old ( $n = 27$ ), and >12 months old ( $n = 31$ ). These groups were compared as to their risk for failure to control IOP (see Fig. 1). No statistically significant difference was found between the three groups, but there may be a trend toward a difference between the youngest group (<2 months old at initial cataract surgery) and the oldest group (>12 months old). As the

**Table 1** Patient summary.

Number included (eyes/patients)	100 eyes/63 patients
Age at secondary IOL implantation in years, median (IQR, range)	6.5 (6.1, 1.1–23.5)
Age at initial cataract surgery in years, median (IQR, range)	0.31 (2.8, 0.01–9.10)
Follow-up duration in months, mean (SD, range)	7.74 (3.11, 2.43–15.00)
Gender, $n$ (%)	27 (42.9%) female/36 (57.1%) male
Demographics, $n$ (%)	46 (73.0%) Caucasian 11 (17.5%) African-American 3 (4.8%) Hispanic 1 (1.6%) Asian 2 (3.2%) other

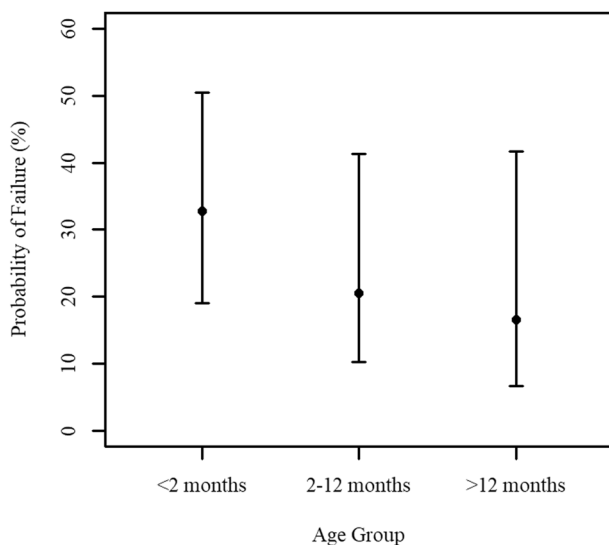
IQR inner quartile range.

**Table 2** Intraocular pressure and antiglaucoma medication results.

Eyes that met failure criteria, <i>n</i> (%)	23 (23%)
Eyes with IOP rise >4 mm Hg, <i>n</i> (%)	14 (14%)
Eyes with IOP drop >4 mm Hg (with no change in antiglaucoma medications), <i>n</i> (%)	15 (15%)
Mean preoperative IOP (mm Hg), mean (SD)	17.27 (5.04)
Mean postoperative IOP (mm Hg), mean (SD)	16.93 (3.60)
Mean change in IOP, (mm Hg), mean (SD)	-0.34 (4.78, <i>P</i> = 0.371)
Eyes requiring increased number of antiglaucoma medications, <i>n</i> (%)	10 (10.0%)
Eyes requiring decreased number of antiglaucoma medications, <i>n</i> (%)	5 (5%)
Eyes on any preoperative antiglaucoma medications, <i>n</i> (%)	24 (24.0%)
Eyes requiring glaucoma surgery, <i>n</i> (%)	0 (0.00%)

**Table 3** Estimated relative risk of failure to control IOP for univariate GEE models.

	Relative risk (95% CI)	<i>P</i>
Age group at initial cataract surgery		
≤2 months ( <i>n</i> = 33) vs. 2–12 months ( <i>n</i> = 27)	1.59 (0.66, 3.85)	0.302
≤2 months ( <i>n</i> = 33) vs. >12 months ( <i>n</i> = 31)	1.97 (0.68, 5.72)	0.213
2–12 months ( <i>n</i> = 27) vs. >12 months ( <i>n</i> = 31)	1.24 (0.39, 3.91)	0.717
<12 months ( <i>n</i> = 60) vs. >12 months ( <i>n</i> = 31)	1.56 (0.56, 4.32)	0.391
Age at IOL Implantation, 1-year decrease	1.08 (1.00, 1.16)	0.059
Sex, female vs. male	1.38 (0.62, 2.83)	0.426
Race, white vs. other	1.57 (0.57, 4.32)	0.426
Preoperative antiglaucoma medication use, yes vs. no	0.80 (0.31, 2.08)	0.652
Trauma, yes ( <i>n</i> = 3) vs. no ( <i>n</i> = 97)	3.08 (1.24, 7.62)	0.015
IOL fixation		
Sulcus ( <i>n</i> = 34) vs. in-the-bag ( <i>n</i> = 30)	1.20 (0.47, 3.08)	0.701
Iris ( <i>n</i> = 26) vs. in-the-bag ( <i>n</i> = 30)	1.12 (0.41, 3.08)	0.820
Sulcus ( <i>n</i> = 34) vs. iris ( <i>n</i> = 26)	1.07 (0.40, 2.83)	0.893

**Fig. 1** Probability of failure according to age at initial cataract surgery. Probability of failure and 95% confidence interval estimated from the univariate GEE model of clinical failure by age category (age at initial cataract surgery: ≤2 months, 2–12 months, >12 months).

age at initial cataract surgery changed, so did the reason for lensectomy, with ectopia lentis being the only etiology listed for children older than 3.9 years at cataract surgery.

When it came to risk for failure to control IOP associated with age at the time of secondary IOL implantation, there was a slight increased risk with younger age (relative risk 1.08 with every 1-year decrease in age, *P* = 0.059).

Three eyes had a traumatic etiology for the cataract, with two out of three failing to control IOP after a secondary IOL was placed. Eyes that had a trauma exhibited a more than threefold increase in the risk of failure relative to eyes that did not have a history of trauma (relative risk, 3.08, 95% CI: 1.24–7.62, *P* = 0.015).

Twenty-four eyes (24%) required at least one antiglaucoma medication prior to IOL implantation. Eighty-five eyes (85.0%) required the same number of medications before and after IOL surgery, while ten eyes (10.0%) required more and five eyes (5.0%) required fewer medications (*P* = 0.165) after IOL surgery. The use of antiglaucoma medications preoperatively actually showed a

small decreased risk of failure to maintain IOP control in the first year after secondary IOL implantation, though the association was not statistically significant (relative risk 0.80, CI: 0.31–2.08,  $P = 0.652$ ).

Further analyses were done based on IOL fixation location. Thirty eyes (30%) had in-the-bag fixation, 34 eyes (34%) had sulcus fixation, 26 eyes (26%) had iris fixation, 6 eyes (6%) had anterior chamber fixation, 2 eyes (2%) had scleral sutured fixation, and 2 eyes (2%) had piggyback IOL placement. Due to the relatively small number of eyes with anterior chamber, scleral suture, and piggyback fixation, further risk analyses included only the larger groups (in-the-bag, sulcus, and iris fixation). There was no statistically significant difference in the risk of failure to maintain IOP control based on IOL fixation location or technique.

## Discussion

The risk of worsening glaucoma after secondary IOL implantation in a child is not well understood. This study aims to shed light not on the IOP issues during the immediate healing after surgery, nor on the long-term glaucomatous progression, but on IOP control in the first year after surgery, once the initial healing has occurred. We excluded the first 2 months after surgery because IOP measurements in the early postoperative period are known to be unstable due to retained viscoelastic, steroid use, and early healing. At our center, some patients receive intracameral triamcinolone near the conclusion of the surgery, whereas all patients are given topical prednisolone for the first month postoperatively. There were no IOP measurements included in this study while an eye was still receiving steroid treatment. Early postoperative IOP spikes are known to occur, especially in eyes with preoperative glaucoma [9].

We decided to use IOP control as the main outcome in this study because it is the most readily available glaucoma-related data in the timeframe of interest in this study. Other glaucoma-related indicators (e.g., optic nerve examination) are commonly performed during later follow-up visits or examinations under anesthesia. Gonioscopy data were not consistently available and were not included in the evaluation of glaucoma progression after surgery.

Our definition of failure was relatively sensitive in order to capture a more precise, objective picture of IOP stability during the first year after surgery. The first part of the definition, the addition of antiglaucoma medication, represents an obvious failure to control IOP. We acknowledge that the second part, the rise in IOP of 5 mm Hg or more, may or may not truly represent a clinically significant worsening of glaucoma in every situation (e.g., a rise from 12 mm Hg preoperatively to 17 mm Hg postoperatively). Therefore, we believe that our rate of failure to control IOP

likely overestimates actual clinical worsening of glaucoma. Long-term follow-up would be required to verify this.

The majority of eyes (77%) did not have worsening of IOP control following secondary IOL implantation within our study timeframe. Of the 23 eyes that showed worsening of IOP control postoperatively, IOP was still able to be controlled medically with no eyes requiring glaucoma surgery during the study period. This tells us that surgery to implant an IOL for aphakia did not, in any eye, result in glaucoma severe enough to require glaucoma surgery.

Most of the literature on glaucoma after secondary IOL implantation has been focused on longer term follow-up and report variable incidences of glaucoma [10–14]. The definitions of “glaucoma” and “glaucoma suspect” also lack standardization between studies. Shenoy et al. reported postoperative glaucoma in 5% of eyes occurring at a median time of 6 months after secondary IOL implantation [15]. Their study excluded all patients with preoperative aphakic glaucoma and used a definition of glaucoma that included elevated IOP and corresponding anatomical changes. Crnic et al. reported a case series of 55 eyes that all received sulcus-fixated 3-piece hydrophobic acrylic secondary IOLs, finding that 11% developed glaucoma, but their definition of glaucoma was not mentioned [16].

Age at cataract extraction has previously been reported as a major risk factor for development of aphakic glaucoma [3–5]. Koch et al. reported glaucoma in 16% of 75 eyes that underwent secondary IOL placement at <30 months of age [17]. All cases of open angle glaucoma developed more than 20 months after IOL implantation, leading them to believe that the glaucoma was less likely caused by the secondary IOL surgery than related to the early age at initial cataract extraction. Wood et al. found a new diagnosis of glaucoma or glaucoma suspect in 18.9% of the eyes in the years after secondary IOL implantation, all of which had initial cataract surgery at <7 months of age [2]. In our study, we found that eyes that had initial cataract surgery at a very young age (<2 months old) had a nearly twofold greater risk of failure to maintain IOP control after IOL implantation compared to eyes that had initial cataract surgery at an older age (>12 months old), although this did not reach statistical significance ( $P = 0.213$ ).

The only risk factor to show statistical significance was traumatic etiology of the cataract. Considering the small sample size of only three eyes with traumatic cataracts, this finding needs to be confirmed with further studies before drawing conclusions.

The use of antiglaucoma medications preoperatively did not show an increased risk of failure during our follow-up period. Although eyes with known glaucoma have a higher risk for early IOP spikes after surgery, our data appear to show that this same group end up maintaining IOP control to a similar degree during the remainder of the first year

after surgery as eyes not on any IOP treatment before surgery [9].

Fixation technique of the secondary IOL (in-the-bag vs. sulcus vs. iris fixation) showed no association with risk of failure. This is an interesting finding as IOL fixation is not at all randomized. At our center, the initial goal, if possible, is to place the secondary IOL in the capsular bag for every case. If in-the-bag fixation is not possible or safe, the IOL is placed in the sulcus or affixed to the iris (i.e., Artisan aphakia iris-claw lens). In some cases, this determination is made preoperatively, while in others it is an intraoperative decision. Since in-the-bag fixation is the technique of choice when a surgery goes smoothly, and sulcus fixation is required more commonly in difficult cases, one might predict that there would be a higher risk of postoperative complications in the sulcus-fixed group, but this did not show to be significantly true.

A small number of eyes (5.0%) required fewer anti-glaucoma medications postoperatively than preoperatively, and 15 eyes (15%) had a decrease in IOP > 4 mm Hg without any change in their number of anti-glaucoma medications. It is not clear why these eyes appeared to improve their IOP status. Overall, placement of a secondary IOL should not be expected to improve IOP control in pediatric aphakic eyes with glaucoma or at risk for glaucoma.

Limitations of our study include its retrospective design, incomplete data leading to the exclusion of some eyes, inherent possible inaccuracies of IOP measurements, unmasked interpreter of IOP to the surgical history, and wide variation of follow-up duration.

In conclusion, our results suggest that there is a modest risk of worsening IOP control in the first year after secondary IOL implantation in children. The broader question of interest behind this study pertains to glaucoma risk after secondary IOL implantation. We hypothesize that worsening of glaucoma directly attributed to the secondary IOL surgery would be seen within the first year after surgery, but that is beyond the scope of this study. Future research with a longer duration of follow-up, inclusion of other glaucoma-related data, and comparison to a control group will help to answer these questions.

## Summary

### What was known before

- Cataract surgery at a very young age is a significant risk factor for the development of aphakic glaucoma.
- Intraocular pressure control can be difficult immediately following secondary IOL implantation in a child.

### What this study adds

- This study adds detailed data pertaining to IOP changes during the first year after secondary IOL implantation.
- This study suggests that very early cataract surgery or a traumatic etiology of the cataract has a relatively higher risk of increased IOP in the first year after secondary IOL implantation.

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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