ORIGINAL ARTICLE

Intraocular Pressure Elevation among Pediatric Patients Given Corticosteroids after Strabismus Surgery

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ABSTRACT

Background. Corticosteroids have been used in ophthalmology for its potent anti-inflammatory and immunosuppressive actions. Although the role of corticosteroid treatment is pivotal in the treatment of numerous inflammatory diseases and as postoperative management of patients who undergo ocular surgeries, intraocular pressure (IOP) elevation has been a significant ocular side effect that could result after steroid use. Evaluating the changes in IOP in pediatric eyes will provide early detection and timely intervention to prevent glaucomatous optic neuropathy.

Objective. This study aimed to determine the incidence of IOP elevation among pediatric patients given corticosteroids after strabismus surgery in a tertiary hospital in Manila, Philippines.

Methods. This is a single-center, retrospective, observational study that employs review of the clinical records of pediatric patients who underwent strabismus surgery between January 2015 and December 2022. This study was conducted last February to November 2023. Data were gathered and descriptively summarized regarding patient demographics, ophthalmologic diagnosis, type of strabismus surgery performed, preoperative and postoperative IOP readings, frequency and duration of postoperative topical steroid use, and treatment received and response to elevated IOP.

Results. Forty-five (28.48%) out of the 158 pediatric patients who had strabismus surgery during the study period met the inclusion criteria for the study. The mean age of pediatric patients was 11.38 ± 5.28 years (range 2-18 years old). There were more males (55.6%) than females. All patients were administered Tobramycin + Dexamethasone eyedrops, ointment or both. The baseline, peak, and net change in IOP were 13.5 ± 2.7 mmHg, 23.1 ± 8.8 mmHg and 10 ± 8.4 mmHg respectively. IOP increased in thirty-seven (82.2%) of the patients from baseline, and 21 (56.7%) of them had a considerable rise. For most patients with considerable rise of IOP, topical steroid medication was either stopped or immediately tapered off. Nine patients received topical IOP-lowering medicine, and most of them returned to normal IOP levels two months following surgery. After then, topical IOP-lowering drugs were stopped.

Conclusion. IOP elevation following strabismus surgery was frequently associated with topical steroid usage, and most patients experienced considerable IOP elevation. It is highly advised to closely monitor IOP following strabismus surgery, particularly in children receiving topical steroid treatment.

Keywords: strabismus surgery, corticosteroid use, intraocular pressure elevation

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INTRODUCTION

Corticosteroids have been used in ophthalmology for its potent anti-inflammatory and immunosuppressive actions. Although the role of corticosteroid treatment is pivotal in the treatment of numerous inflammatory diseases and as postoperative therapy for various ocular surgeries, intraocular pressure elevation has been a significant ocular side effect that could result after steroid use.[1] If intraocular pressure (IOP) elevation is of sufficient magnitude and is not treated, glaucomatous optic neuropathy can develop.[2]

Corticosteroid-induced glaucoma is usually characterized by elevated intraocular pressure after corticosteroid use and can result in irreversible visual field and vision loss.[2,3] In these cases with elevated IOP, patients especially children may not report any symptoms until significant damage has been done and the disease has reached an advanced stage. The term "steroid-induced ocular hypertension" refers to a rise in IOP of more than 10 mmHg over baseline. Individuals who take glucocorticoids and see an increase in IOP are referred to as "steroid responders." One explanation for the process is the increased accumulation of non-digestible glycosaminoglycans (GAG) in the trabecular meshwork caused by steroid usage leading to IOP elevation. Furthermore, research has shown that steroids decrease the release of lysosomal enzymes that hydrolyze GAG. As a result, the indigestible GAG will raise resistance in the aqueous outflow by exerting an osmotic impact, causing swelling, and ultimately blocking the trabecular meshwork. The accumulation of debris in the anterior chamber angle as a result of the steroid-induced decrease in leukocyte activity is another cause.[4]

In reaction to steroid usage, a number of risk factors for elevated IOP have been found. Age, genetic predisposition, glaucoma diagnosis or family history, extreme myopia, and connective tissue disease are a few of these.[2] IOP elevation can happen as early as the first postoperative day and is more likely the longer and more often steroids are used. The IOP will thereafter stabilize once the use of steroids is stopped. On the other hand, prolonged steroid usage might result in an IOP that remains elevated even after stopping the medication.[4]

Elevated Intraocular pressure can occur due to exogenous corticosteroid administration through the topical, intraocular, periocular, oral, and intravenous routes. The topical route was found to be more common to cause steroid-induced intraocular pressure elevation. Dexamethasone, Prednisolone, Betamethasone, and Clobetasone, which are the older generation corticosteroids, more commonly cause IOP elevation compared to the newer topical steroids such as Loteprednol etabonate, Difluprednate, and Rimexolone. The IOP elevation with older-generation corticosteroids may range from 6 mmHg to 22 mmHg.[2] Another factor that determines the potency of the steroid is its chemical structure. Acetate is more lipophilic and permeates the cornea better than phosphates which are relatively hydrophilic; hence, it would be expected that Dexamethasone acetate 0.1% can cause a greater rise in IOP than other kinds of preparation.[2] Less potent corticosteroids, such as Fluorometholone have been reported to have reduced risk of steroid-induced elevation in IOP compared with other steroid therapy because of its poor corneal penetration. However, the anti-inflammatory action is correspondingly reduced.[5] Kupferman and colleague report that the mean time to IOP increase was much longer with Fluorometholone than with previously stated steroid medication and that the IOP elevation was less with Fluorometholone than with Dexamethasone and Prednisolone.[6] Among corticosteroids, Loteprednol etabonate is distinct in that its molecule has a metabolically labile component that permits quick metabolism and degradation after glucocorticoid receptor activation, hence reducing the likelihood of adverse effects.[7] According to Roberti et al., Loteprednol induces a clinically significant IOP increase in a small proportion of patients (1.7 – 2.1%) compared to older-generation corticosteroids.[2]

Armaly divided the ocular hypertensive response to topical steroids into three groups. These three responses are as follows: (i) mild response, defined as a pressure increase of less than 6 mmHg (mean of 1.6 mmHg); (ii) moderate response, defined as an IOP rise of 6 to 15 mmHg (mean of 10 mmHg); and (iii) severe response, defined as a pressure rise of more than 15 mmHg (mean of 16 mmHg). This research showed that 5% of respondents were strong steroid responders, 28.8% were intermediate responders, and 66.2% had a low reaction. This study by Armaly has been a landmark in the IOP elevation classification after topical steroid therapy.[8]

Adult cases of the ocular hypertensive corticosteroid response are well-researched. To the best of our knowledge, no local investigation is available, and there are only a few clinical trials addressing IOP rise in a cohort of children treated with topical steroids on a regular basis after strabismus surgery. Furthermore, it is uncertain if early therapies may be necessary for steroid-induced glaucoma and what the risk factors are for children with increased IOP. Given that corticosteroid medication is a crucial component of postoperative care, assessing the changes in intraocular pressure in these young eyes will yield information for therapeutic decision-making.

OBJECTIVES

This study aims to determine the incidence of intraocular pressure elevation among pediatric patients given corticosteroids after strabismus surgery in a tertiary hospital in Manila, Philippines.

Specifically, this study aims to:

1. Describe the demographics of patients based on age and gender.
2. Determine the ocular characteristics such as ophthalmologic diagnosis, age at time of surgery, and type of surgery done.

3. Determine the steroid treatment given such as type of steroid therapy, dosing schedule, and duration of steroid treatment.
4. Determine the baseline preoperative and postoperative IOP, the direction of net change in IOP, classification of net increase in IOP, and time to reach peak IOP.
5. Determine if there are treatments done to control increased IOP and their response to the treatment.

MATERIALS AND METHODS

Study Design

This is a single-center, retrospective, observational study that employs hospital chart review of pediatric patients 18 years old and below who underwent strabismus surgery of any type from January 1, 2015, to December 31, 2022, under the Pediatric Ophthalmology Service of the Philippine General Hospital Department of Ophthalmology and Visual Sciences. This study is compliant with the Principles of the Declaration of Helsinki and was conducted after approval of the UP Manila Research Ethics Board.

Population

All pediatric patients who underwent strabismus surgery of any type, 18 years old and below, from January 1, 2015, to December 31, 2022, who were given postoperative steroid treatment of any type and had a baseline and postoperative intraocular pressure with at least 6 weeks of follow-up were included. Exclusion criteria included patients with less than 6 weeks of follow-up, lost and incomplete medical records, preoperative glaucoma diagnosis, and presence of other surgical procedures done at the same time of strabismus surgery or within the 6 weeks postoperative period such as retinal surgery (pars plana vitrectomy, intravitreal gas or silicone injection, encircling band, scleral buckle procedure), glaucoma surgery performed for reasons other than steroid-induced glaucoma (trabeculotomy, goniotomy, trabeculectomy, glaucoma drainage device implantation), orbit and plastics surgery (ptosis repair, nasolacrimal duct obstruction surgery such as probing, stenting, balloon dilatation and dacryocystorhinostomy), corneal surgery (corneal laceration repair, EDTA chelation), cataract surgery (irrigation & aspiration of cataract, pars plana lensectomy, secondary Intraocular lens implantation, and membranectomy/posterior capsulotomy).

Study Outcomes

The primary outcome of this study is the measurement of intraocular pressure postoperatively at any time during the follow-up period. The secondary outcome was the length of time IOP is controlled, and the intervention required.

Data Collection

Of the 158 pediatric patients who underwent strabismus surgery from 2015-2022, 111 charts were retrieved. Out of the 111 charts, 22 patients had no intraocular pressure determination and 44 had only baseline intraocular pressure determination and/or had less than 6 weeks of follow-up. Only 45 patients met the inclusion criteria and were included in the study.

Prior to surgery, every patient had evaluations for visual acuity, strabismus, anterior segment inspection using a slit-lamp biomicroscope, and posterior segment examination. Intraocular pressure measurements were performed using a Goldmann™ applanation tonometer for cooperative patients or the Icare Pro™ for uncooperative or very young patients. Three readings were obtained using the Icare Pro™ and the mean value was used for analysis. All children had surgery under general anesthesia. Postoperatively, all patients were administered a combination tobramycin dexamethasone ointment or eyedrops or both as twice daily to four times daily dosing.

The patient's age, sex, ophthalmologic diagnosis, age at the time of surgery, and type of surgery were collected. The measures of intraocular pressure preoperatively, and postoperatively at any time during the follow-up period were collected. The last recorded IOP value before strabismus surgery in the operative eye was used as the baseline. The highest IOP recorded in the chart at any point during the postoperative period was considered the peak postoperative IOP value. This applied to the affected eye in monocular surgery, the right eye in case of bilateral surgery with equal number of muscles operated on, or the eye that had the greatest number of procedures in cases of a 3 or more muscle surgery. It was also noted how long it took to attain the greatest IOP value. The greatest postoperative IOP less the baseline IOP was used to compute the net change in IOP. The type and dosage of steroid treatment were determined. The patients were then categorized using the Armaly classification system based on how well they responded to topical steroids: (i) low response, defined as a pressure rise of less than 6 mmHg (mean of 1.6 mmHg); (ii) intermediate response, defined as a pressure rise of between 6 and 15 mmHg (mean of 10 mmHg); and (iii) severe response, defined as a pressure rise of more than 15 mmHg (mean of 16 mmHg).

The intervention done to address the increased IOP and their management response was also documented. Patients with significant increases in their IOP were managed as follows: (1) started on topical IOP-lowering medications, (2) decreased the frequency of topical steroid, (3) shifted to another class of steroids, or (4) stopped the steroid medication.

Statistical Analysis

Data management and analysis were conducted with IBM-SPSS version 21. For numerical variables, means, ranges, and standard deviations were used to describe the variables in a descriptive manner. We employed proportions and frequencies for categorical variables.

RESULTS

Demographic and Clinical Characteristics

A total of 158 pediatric patients had strabismus surgery during the study period however, only 45 (28.48%) patients were included in the study. Twenty-two (13.92%) patients had no IOP determination while 44 (27.85%) patients had only a baseline IOP or were not able to complete the 6-week follow-up period. Forty-seven (29.75%) patients had lost and/or incomplete medical records. Majority were males (n=25, 55.6%) than females. The mean age at surgery was 11.38 years (range: 2-18 years). Twenty-nine (64.4%) patients had esotropia, 12 (26.7%) patients had exotropia, three (6.7%) patients had Duane syndrome and one (2.2%) had monocular elevation deficiency. The majority of the patients had monocular recession and resection surgery (n=13, 28.9%). 10 (22.2%) had bilateral medial rectus recession while one (2.2%) had bilateral medial rectus recession with posterior fixation suture (faden operation). Seven (15.6%) patients had bilateral 3 horizontal muscle surgery, eight (17.8%) patients had combined horizontal and vertical muscle surgery, one (2.2%) had combined transposition and horizontal muscle surgery, two (4.4%) patients had transposition surgery, while another two (4.4%) had muscle re-operation surgery, and one (2.2%) patient only had one horizontal muscle surgery (Table 1). Figure 1 summarizes the age and sex distribution of pediatric patients.

Table 1. Clinical and Demographic Profile of Pediatric Patients who Underwent Strabismus Surgery from January 2015 to December 2022 (n=45)

Profile	Frequency	%
Age at surgery (years)		
2-5	7	15.6
6-11	18	40.0
12-18	20	44.4
Sex		
Female	20	44.4
Male	25	55.6
Ophthalmologic diagnosis		
Esotropia	29	64.4
Exotropia	12	26.7
Duane syndrome	3	6.7
Monocular elevation deficiency	1	2.2
Type of surgery done		
Monocular recession and resection	13	28.9
Bilateral medial rectus recession	10	22.2
Combined horizontal and vertical muscle	8	17.8
Bilateral 3 horizontal muscle	7	15.6
Muscle re-operation	2	4.4
Transposition surgery	2	4.4
Bilateral MR recession + Faden operation	1	2.2
Combined transposition and horizontal muscle	1	2.2
Unilateral 1 horizontal muscle	1	2.2

Type of steroid, dose, and duration of use

Majority (n=20, 44.4%) of the patients were placed on antibiotic-steroid combination of tobramycin with dexamethasone ointment and eyedrops postoperatively. Thirteen (28.9%) patients were placed on tobramycin with dexamethasone eyedrops alone and 12 (26.7%) patients were placed on tobramycin with dexamethasone ointment. (Figure 2) All patients were also given topical eye lubricant. Thirty-two (71.1%) patients used steroids four times daily dosing and others were on three times a day dosing schedule (n=13, 28.9%).

Thirty-two (71.1%) patients used steroids four times daily dosing and others were on three times a day dosing schedule (n=13, 28.9%). Most of the patients were placed on steroid therapy for 2-4 weeks (n=20, 44.4%), 11 (24.4%) patients were placed for 4-8 weeks, nine (20%) patients for 8 days – 2 weeks, three (6.7%) patients only had one week steroid use and was eventually discontinued, and two (4.4%) patients used steroids for 8-12 weeks (Table 2).

Intraocular pressure changes

The intraocular pressure readings of the affected eye in monocular surgeries, or the right eye of patients undergoing bilateral operations, or the eye that had the greatest number

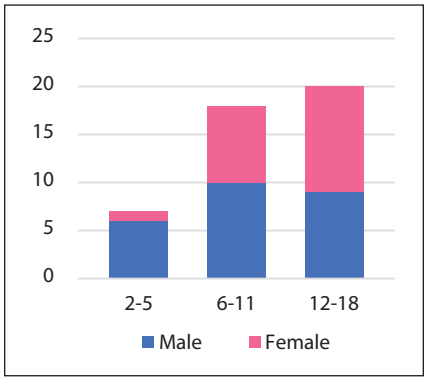

Figure 1. Age and sex distribution of 45 included pediatric patients,

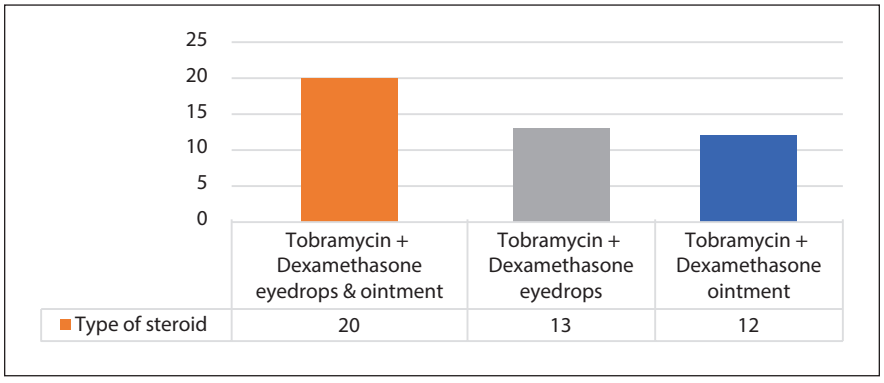

Figure 2. Type of steroid used.

of procedures in cases of a three or more muscle surgery were analyzed. Of the patients, thirty-seven (82.2%) had higher IOP from baseline, six (13.3%) had decrease IOP from baseline and two (4.4%) patients had the same IOP as their baseline (Table 3). Furthermore, those patients who had an increase IOP from baseline were categorized based on the Armaly classification system. Sixteen (43.2%) patients were classified as low responders, ten (27%) patients were intermediate responders, and eleven (29.7%) patients were severe responders (Table 4).

Baseline IOP was 13.5 ± 2.7 (range of 10–20) mmHg on average. The mean peak IOP was 23.1 ± 8.8 mmHg (with a range of 12 - 47.3 mmHg). In the low response group, the mean pressure rise was 3.06 ± 1.81 (2 - 6) mmHg, in the intermediate response group, the IOP rise was 10.9 ± 3.35 (7 - 14.67) mmHg, and in the response group with severe IOP, it was 19.17 ± 8.26 (16 – 35.33) mmHg (Table 5).

Figure 3 shows IOP response with medications used. Thirteen patients were started on Tobramycin + dexamethasone eyedrops for 4 x daily dosing. Out of 13, seven had low increase, two had intermediate increase, two had severe increase, one had decrease response, and one remained unchanged. Three patients were started on Tobramycin + dexamethasone ointment 4 x daily dosing and all had intermediate increase. Nine patients were started on Tobramycin + dexamethasone ointment 3x daily dosing and revealed five patients in low increase, one had intermediate increase, another one had severe increase, and two patients had a decrease response. Majority of our patients were started on Tobramycin + dexamethasone eyedrops and ointment for 4 x daily dosing. Eight out of 18 patients had severe increase in IOP, three had intermediate increase, four had low increase, two had a decrease response, and one remain unchanged. Lastly, two patients were started in both Tobramycin + dexamethasone eyedrops and ointment 3x daily dosing. One had low increase and the other two had intermediate increase.

Table 2. Duration of Steroid Use

Variable	Frequency / Value (%)
Duration of steroid used	
1 – 7 days	3 (6.7)
8 days – 2 weeks	9 (20)
>2 – 4 weeks	20 (44.4)
>4 – 8 weeks	11 (24.4)
>8 – 12 weeks	2 (4.4)

Table 3. Direction of Intraocular Pressure Change

Variable	Frequency / Value (%)
Direction of IOP change	
Increase	37 (82.2)
Decrease	6 (13.3)
No change	2 (4.4)
Total	45 (100.0)

Table 4. Categorization of Intraocular Pressure Variation

Variable	Frequency / Value (%)
Categorization of net IOP change	
Low responders	16 (43.2)
Intermediate responders	10 (27.0)
Severe responders	11 (29.7)
Total	37 (100.0)

Table 5. Average Intraocular Pressure Readings

Variable	Mean ± SD (Range)
IOP values	
Baseline IOP	13.5 ± 2.7 (10 - 20) mmHg
Maximum IOP	23.1 ± 8.8 (12 - 47.3) mmHg
IOP net change	
Low responders	3.06 ± 1.81 (2 - 6) mmHg
Intermediate responders	10.9 ± 3.35 (7 – 14.67) mmHg
Severe responders	19.17 ± 8.26 (16 – 35.33) mmHg

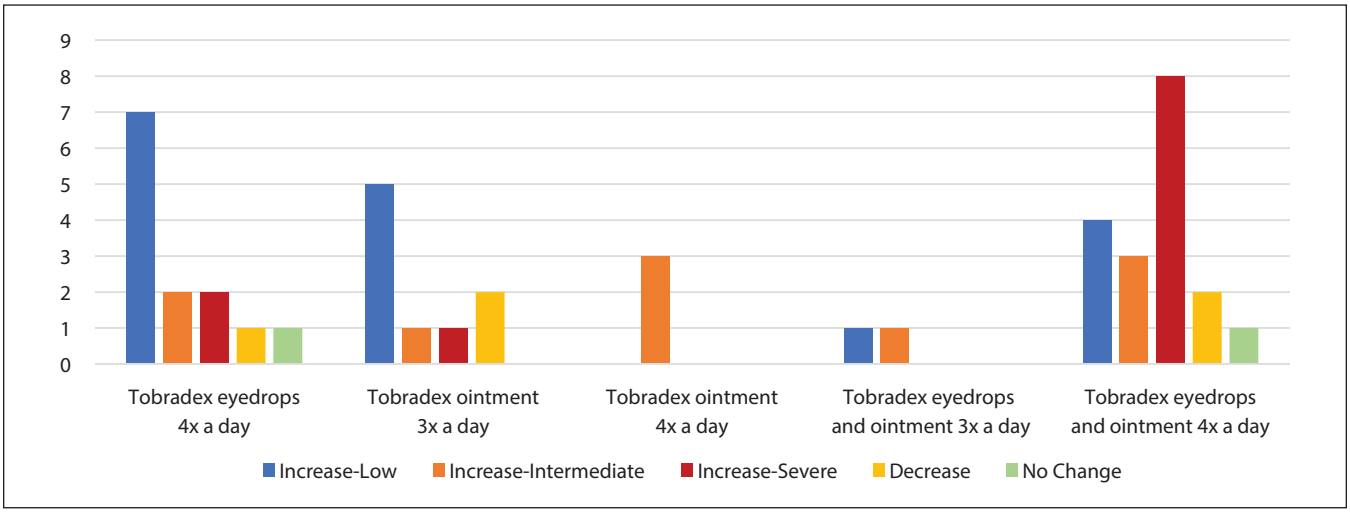

Figure 3. Intraocular pressure response in medications used.

Table 6. Time to Reach Peak Intraocular Pressure

Variable	Mean ± SD (Range)
Time to reach peak IOP (in weeks)	
Overall	2.94 ± 2.41 (0.1 - 8) weeks
Low	3.35 ± 2.55 (0.1 - 8) weeks
Intermediate	2.31 ± 2.19 (0.1 - 8) weeks
Severe	2.97 ± 2.24 (0.7 - 7) weeks

Note: 0.14 is equivalent to 1 day, 0.70 is equivalent to 5 days

The highest IOP was reached in 2.94 (0.1 – 8) weeks on average. For those classified under low response – it took an average of 3.35 weeks to reach peak IOP, 2.31 weeks for those who had intermediate response and 2.97 weeks for those under severe response (Table 6). Noted on Figure 4 is the duration of steroid use and intraocular pressure change in our patients. Majority who were placed on steroids for 2-4 weeks had an increase in their IOP. Three patients who had severe response in their IOP in the first week of treatment were all given a combination of Tobramycin + Dexamethasone eyedrops and ointment.

Figure 5 shows changes in intraocular pressure with age. In our study, the 2 - 5 age group had the highest change in their IOP where five patients or 71.43% belonged to the severe response category. Those in the 6 – 11 age group belonged equally to the low and intermediate responders. Majority of patients 12 – 18 years old were classified under low responders, three patients were intermediate responders and only 2 patients were severe responders.

Treatment and time to normal IOP

For most pediatric patients with severe IOP elevation, the frequency of topical steroid medication was quickly tapered off, while some patients were switched to another

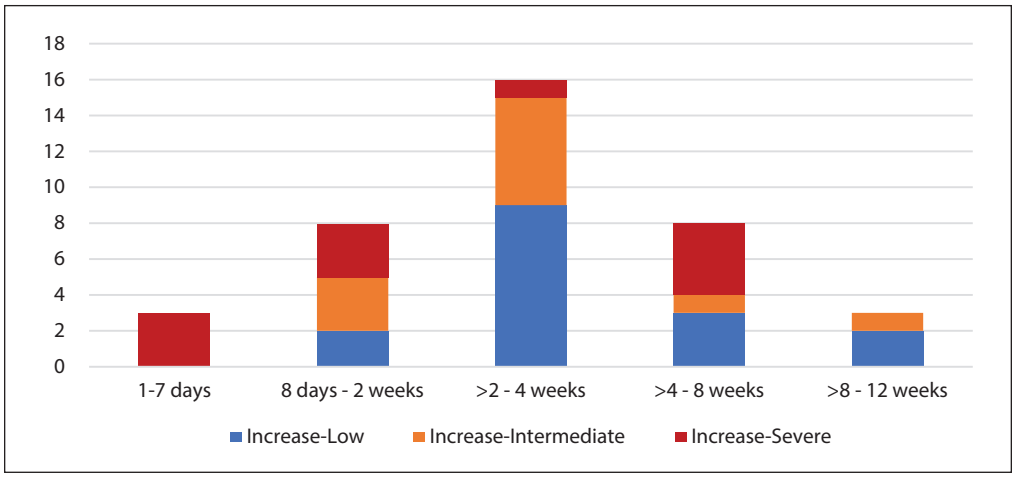

Figure 4. Duration of steroid use and IOP change.

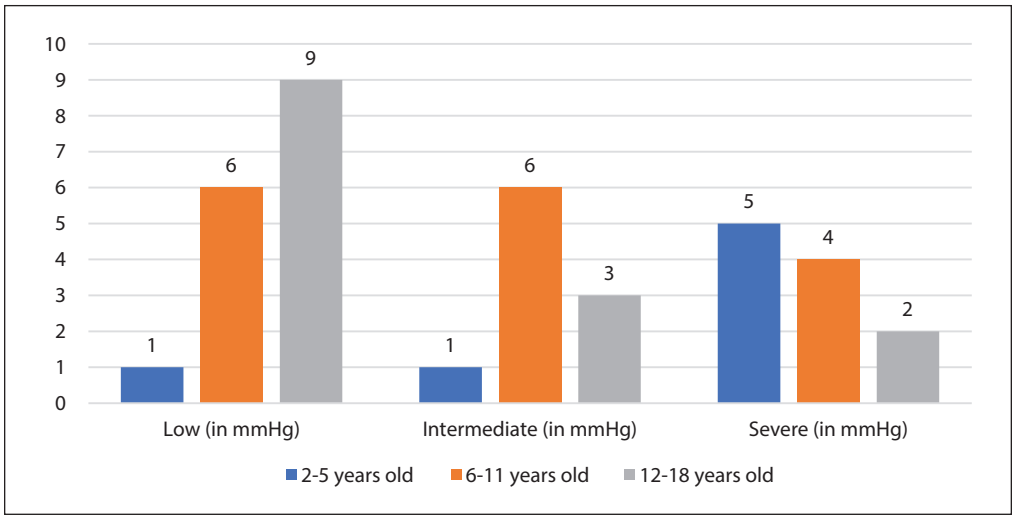

Figure 5. Age-related variations in intraocular pressure.

Table 7. Management Done and Time to Decrease IOP

Variable	n	Time to decrease IOP
Management done to address increase in IOP		
Decreased dosage	13	2.3 weeks (1 – 4 weeks)
Shifted to other class	9	3.4 weeks (2 – 6 weeks)
Shifted to other class and started on anti-glaucoma meds	6	2.9 weeks (3 days – 6 weeks)
Stopped steroids	6	3.5 weeks (1 – 6 weeks)
Stopped steroids and started on anti-glaucoma meds	3	4.6 weeks (2 – 6 weeks)

drug class (e.g., loteprednol eyedrops and tobramycin). Of the 11 patients who had a severe level of IOP response, two patients were immediately advised to stop the steroid treatment while nine (81.82%) patients were either stopped on steroids or shifted to other class of steroids and started on topical IOP lowering medications. Eight were placed on topical beta-blocker and one was started on topical carbonic-anhydrase inhibitor.

Of those patients who were tapered off on steroids, IOP decrease after an average of 2.3 weeks. Those who were discontinued on steroids and started on IOP-lowering medications were the longest to decrease the IOP at an average of 4.6 weeks. This may be due to the different time interval of their follow-up, or a longer time needed to decrease the IOP after an episode of very high rise in IOP. Nine patients who were shifted to other class of steroids had a decrease in IOP after an average of 3.4 weeks. Six patients who were immediately stopped on steroids took an average of 3.5 weeks. While six patients who were shifted to other class of steroids and started on anti-glaucoma medications had an average of 2.9 weeks before a decrease in IOP (Table 7). Additional analysis was done on nine patients who needed additional anti-glaucoma medications. Five (55.56%) had decrease in intraocular pressure after two weeks of therapy, two (22.22%) after three weeks, one (11.11%) after one week, and another one (11.11%) after three days. Within the first two months following surgery, majority of these patients had normalized IOP. In two patients, the IOP recovered to normal range at three and four months post-procedure, respectively.

To account for the variable follow-up of our participants, we include the proportion at presentation and the incidence rate. The proportion at presentation of pediatric patients with increase intraocular pressure after strabismus surgery is 80% or 8 in 10 individuals. The incidence rate is 8.7 cases per 1,000 eye-years.

DISCUSSION

The most prevalent ocular hypertensive response seen in this study (43.3%) was the low level of response. The mean increase in IOP was 3.06 mmHg. The group with a severe level of reaction (27.0%), whose mean IOP rise was 19.17 mmHg, and the group with a moderate response (27.0%), whose mean IOP rise was 10.9 mmHg, came next respectively. This is comparable to reports by Armaly and Biedner et al. but dissimilar to findings by Ugalahi et al. and Lee et al. where most participants had an intermediate level of response with 41.7% and 56.3%, respectively.[4,8-10] This could be because most participants in Armaly's study (71%) were between the ages of 21 and 25 years old, and 44% of those in our study were in the 12-18 year old age range.

It has been demonstrated that the patient's age affects the amount of intraocular pressure elevation that occurs when ocular corticosteroids are used following surgical operations. Ohji et al. were able to examine the effects of topical dexamethasone on patients who had squint surgery in two age groups: patients over 10 and children under 10 years old.[11] In contrast to older children >10 years old, whose IOP did not rise over 20 mmHg, nine out of ten younger children had high intraocular pressure of >20 mmHg, according to their study. Children aged 5 and under also had a greater incidence of IOP elevation, according to research by Lee et al. and Parekh and colleagues discovered that over 60% of children, especially those under the age of six, had an increased IOP in response to steroids.[10,12] According to this research, children's intraocular pressure increased more severely and with a faster onset than that of adults. Thus it is recommended to be more prudent in using steroids in this age group below 6-10 years old. The age range of 2 to 5 years showed the largest change in IOP in our study, with the majority (71.43%) falling into the severe response category. Ng et al. and Reme et al. have noted that the enhanced ocular hypertensive response to topical steroids in children compared to adults is clearly complicated, with the key contributing factor believed to be the structural and functional immaturity of the trabecular meshwork.[13,14] They found that while the anterior chamber angle's constituent structures are all present in the human eye from birth, the formation and development of these structures don't stop until the age of eight. Compared to adults, children may experience an earlier onset, more severe presentation, and faster progression of the elevated IOP, and may subsequently lead to glaucomatous damage.

$$\text{Proportion at presentation} = \frac{\text{Number of participants with event at study entry}}{\text{total number of participants at study entry}} = \frac{37}{45} = 0.8$$

$$\text{Incidence rate} = \frac{\text{Number of new events during follow-up}}{\text{total follow-up eye-years}} = \frac{37 \text{ cases}}{4.25 \text{ eye-years}} = 8.7 \text{ cases}$$

Table 8. Comparison of the Ocular Response to Dexamethasone across Several Studies

Variables	Anotado & Santiago (2023)	Armaly (1965)	Biedner et al. (1980)	Ohji et al. (A) (1991)	Ohji et al. (B) (1991)	Kwok et al. (1997)	Lee et al. (2006)	Ugalahi et al. (2022)
Age (in years)								
Mean	11.38 ± 5.28		9.7	5.5	20.6	6.1 ± 0.56	6.5 ± 2.7	20.5 ± 13.6
Range	2 to 18	16 to 47	4 to 19	3 to 8	12 to 49	<10	3 to 16	5 to 57
Sample size	45	80	44	11	9	16	96	36
Administration frequency (times/day)	3 to 4	3	4	3	3	6	2 to 3	3 to 4
Administration period (weeks)	4.27 ± 2.59	4	6	At least 2	At least 2	4	3	6.3 ± 2.7
Mean baseline IOP	13.5 ± 2.7		11.2 ± 2.0			15.18 ± 2.89	13.6 ± 2.9	12.9 ± 2.6
Mean peak IOP (mmHg)	23.1 ± 8.8					30.66 ± 8.35	20.6 ± 4.9	21.3 ± 6.8
Mean time to reach peak (days)	20.58 ± 16.8					15.56 ± 8.29	8.5 ± 5.9	23 ± 12
IOP net change								
Low responders	43.2% (16)	66.2% (53)	89% (39)	0% (0)	77.8% (7)	6.25% (1)	35.4% (34)	30.6% (11)
Intermediate responders	27.0% (10)	28.8% (23)	9% (4)	45.5% (5)	0% (0)	37.5% (6)	56.3% (54)	41.7% (15)
Severe responders	29.7% (11)	5% (4)	2% (1)	36.4% (4)	0% (0)	56.25% (9)	8.3% (8)	16.7% (6)

The second most frequent level of response seen in this study was severe IOP response. Most patients with severe IOP were started with both tobramycin-dexamethasone eyedrops and ointment. The topical route was found to be more common to cause steroid-induced intraocular pressure elevation. Dexamethasone, Prednisolone, Betamethasone, and Clobetasone, which are the older generation corticosteroids, more commonly cause IOP elevation compared to the newer topical steroids such as Loteprednol etabonate, Difluprednate, and Rimexolone. The IOP elevation with older-generation corticosteroids may range from 6 mmHg to 22 mmHg.[2] Another factor that determines the potency of the steroid is its chemical structure. Acetate is more lipophilic and permeates the cornea better than phosphates which are relatively hydrophilic; hence, it would be expected that Dexamethasone acetate 0.1% can cause a greater rise in IOP than other kinds of preparation.[2] According to a study by Clark and colleagues, compared to untreated eyes with morphologically normal angles, hypertensive eyes treated with dexamethasone showed thicker trabecular beams, decreased intertrabecular spaces, thicker juxtacanalicular tissue, activated trabecular meshwork cells, and higher amounts of amorphous granular extracellular material, particularly in the juxtacanalicular tissue and beneath the endothelial lining of Schlemm's canal. They concluded that Dexamethasone treatment led to ocular hypertension in approximately 30% of the Dexamethasone-treated eyes. Steroid treatment resulted in structural changes in the trabecular meshwork similar to those reported for corticosteroid-induced glaucoma and open-angle glaucoma.[15] Our finding is consistent with the findings of Kwok et al., which showed that 56.25% of the subjects experienced significant IOP elevation.[5] This could be a result of their study's higher frequency of steroid use and lower sample size.

After strabismus surgery, Ugalahi et al. observed the following changes in IOP: an increase that peaked in the first two weeks and a drop that persisted for one month.[4] In our study, intraocular pressure changes followed the same trend, increasing in the first two weeks from preoperative levels and then reducing by 2-4 months after surgery. The average duration to reach maximum IOP was also similar to that of Ugalahi et al. (3.3 weeks) compared to our investigation (2.94 weeks).[4] In contrast, a study by Lee et al. revealed a shorter mean time—1.2 weeks—to attain peak IOP.[10] Given that children have been shown to experience a rise in their IOP more quickly than adults, it is possible that this is because the participants in their research were younger (mean age 6.5 ± 2.7 years) than those in our study (mean age 11.38 ± 5.28 years) (Table 8).

Our study, like the other researches, found that even in the absence of IOP-lowering drugs, IOP returns to normal levels after steroid reduction and/or switching to other types of steroids. Therefore, the first step in controlling IOP increase is to taper off steroid drugs. In our investigation, individuals with considerably increased IOP were started on IOP-lowering drugs to reduce the amount of time that the harmful levels of elevated IOP exposed and damaged the optic nerve. At their subsequent follow-up appointment, all of them had a reduced IOP, and it was noted that they all responded well to the IOP-lowering drugs.

We recognize that given the retrospective approach of our study, missing or incomplete records, and the small number of patients who met the study's eligibility requirements are some of its limitations. Also, surgeries were varied and were performed by different surgeons. However, all surgeries were done with either the fellow or senior resident of the service with the assistance of a trained pediatric ophthalmologist consultant with special expertise in strabismus surgeries. Different steroid regimens were also commenced in our

patients, as such it would be better to follow a similar treatment protocol for proper comparability. Despite this, our results highlight the significance of tracking changes in intraocular pressure (IOP) in pediatric patients receiving topical steroid treatment following strabismus surgery, as some of them showed notable IOP responses.

CONCLUSION

Our study reported that 82.2% of pediatric patients given corticosteroids had increased IOP from baseline after strabismus surgery. Low level of IOP increase were commonly encountered after strabismus surgery, and most children less than 5 years old had a severe level of IOP response. In most of our patients, IOP returned to normal after tapering or shifting to another steroid class. As this study showed, in extreme situations, medication may be required to decrease IOP.

Therefore, we recommend that after strabismus surgery, close monitoring of IOP in patients receiving topical steroid treatment is highly advised. This has particular significance since the patient's postoperative assessment may not consistently prioritize IOP monitoring. This will allow us to prevent steroid-induced glaucoma by using early therapy. To obtain a more comprehensive understanding of IOP assessment and identify other factors that may influence its rise, a prospective study is still advised. Additionally, it will guarantee consistency in the process and accurate patient categorization. The authors propose to revise the postoperative steroid regimen in terms of the kind of steroid, how often it is administered, and how long it is used following strabismus surgery.

Lastly, our study showed that children who underwent strabismus surgery had exaggerated ocular hypertensive response to steroid treatment, thus it is essential to include intraocular pressure monitoring as a routine measurement while they are still under topical steroid therapy.

Statement of Authorship

Both authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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