Using Hyperopia Measurements to Predict Accommodative Esotropia Surgical Correction in Children

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Abstract

Background:

Esotropic strabismus is a condition in which the eyes are not properly aligned with each other. In children, esotropia often develops into impaired stereopsis and/or amblyopia which significantly increases the risk for the child of becoming blind by losing vision in the amblyopic eye due to disconnected communication with the brain. Early identification and treatment of esotropia in children is critical, as doing so may prevent permanent loss of vision.

Although some literature suggests children with hyperopia greater than +3.5 diopters may have a higher risk of developing accommodative esotropia, which can generally be controlled with prescription lenses, a great deal of uncertainty remains regarding this exact measurement. A gap in literature also seems to exist in the manner in which severity of hyperopia in esotropic children of this age group may or may not be used to predict the need for correctional surgery. Of the research we found, much of it took place in countries outside the United States, so our research will also attempt to fill this population gap.

Materials and Methods:

This is a retrospective review of children between the ages of two and six years who were diagnosed with strabismus between the years of 2008-2010. 350 patient charts were reviewed, of which 238 were excluded due to diagnosis of pseudostrabismus, leaving 112 patients meeting study criteria. Data collected and analyzed included age, degree of hyperopia at initial presentation, misalignment measurements, surgery status, amblyopia treatment duration before surgery, and postsurgical hyperopia and alignment measurements.

Results:

Our data suggests that children with strabismus who are older than four years have an increased risk of requiring surgery over patients fours years and younger. In our patient population, the mean right eye hyperopia measurement was 3.4 diopters; mean left eye measurement was 3.5 diopters. Our data indicates that in children with strabismus for every 1.0 increase in hyperopia measurement the likelihood of the child needing surgery decreased by

30% in the right eye (p-value 0.007) and by 25% (p-value 0.019) in the left eye. This data indicates that children with strabismus and lesser degrees of hyperopia are less likely to respond to treatment and more likely to require surgery than children with strabismus who have greater degrees of hyperopia.

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Introduction/Significance

Background

Strabismus and amblyopia

Strabismus is a condition in which the eyes are not properly aligned with each other. The misalignment can be constant or intermittent, can be esotropic (one or both eyes turning in - convergent) or exotropic (one or both eyes turning out – divergent), and is often accompanied by abnormal motility of the eyes, decreased vision, ocular discomfort, double vision, abnormal head posture, or headaches. It is important to distinguish between congenital and acquired strabismus, as some forms of acquired strabismus can be caused by life-threatening or vision-threatening conditions. For some individuals, strabismus may even result in permanent vision loss.

In children, strabismus often develops into impaired stereopsis (the process responsible for the 2D-to-3D reconstruction of the depth dimension in our visual world) [11] and/or amblyopia (when vision in one eye is reduced due to the eye and the brain not working together properly), which significantly increases the risk for the child of becoming blind by losing vision in the amblyopic eye due to disconnected communication with the brain and/or the non-amblyopic eye due to disease or trauma[4]. Early identification and treatment of strabismus in children is critical, as doing so may prevent amblyopia.

Prevalence of strabismus in the general population is estimated to be from 2% to 5%, with between 5 and 15 million individuals in the United States having the condition[5]. In a 2008 birth cohort study of 7,825 seven-year-old children, 2.3% were found to have manifest strabismus, 3.6% had past/present amblyopia, and 4.8% were hyperopic[6]. The National Health Survey of individuals 4-74 years of age found exotropia (2.1%) to be more prevalent than esotropia (1.2%) in the U.S. population, but several other studies of clinical populations reported that esotropia appears 3 to 5 times as often as exotropia in children.

Esotropia: Accommodative refractive vs. Partially accommodative and Nonaccommodative

The focus of this study will be on accommodative and partially accommodative esotropia, which are both convergent forms of strabismus and acquired forms of esotropia.

Both forms are highly associated with hyperopia, but in some cases, normal binocular vision has existed prior to the onset of either condition[2].

Accommodative esotropia typically presents between the ages of one and eight years with an average age of onset of about two years[12]. Although it may be precipitated by illness, fever, or trauma, accommodative esotropia is characterized by and is usually related to excessive convergence in a child with bilateral hyperopia (farsightedness – distant objects are clear but close objects do not come into proper focus). Correction of the hyperopia eliminates the esotropia and results in normal alignment at distance fixation. In cases of accommodative esotropia with a high accommodative convergence to accommodation ratio (AC/A), a persistent or intermittent esotropia may persist with near fixation even after hyperopic correction. Such cases will not be discussed in this investigation.

Partially accommodative esotropia describes those children who, upon correction of hyperopia with corrective lenses, experience only a partial improvement of esotropia at distance and near (measured through the prism and alternate-cover test). Children who experience no improvement of esotropia with hyperopia correcting lenses are described as having nonaccommodative esotropia. Due to the fact that treatment for both of these more severe forms of esotropia is extraocular muscle surgery, the difference between them will not be distinguished at this time.

Treatment of Esotropia

Optical correction of hyperopia is the first line method of treatment for esotropia with the goal of restoring alignment and, especially in very young patients, allowing binocularity to develop. In the majority of cases, full correction of refractive error is prescribed, but in older children, undercorrection of the hyperopia is sometimes helpful in improving adherence. After refractive correction with eyeglasses, improved alignment may take several weeks.

If eyeglasses are ineffective in aligning the eyes, children with esotropia should undergo extraocular muscle surgery for correction. Except for acquired symptomatic deviations in older children, small-angle deviations of more than 12 prism diopters at distance or near are usually considered for surgery.[13]

Significance and Rationale

Hyperopia is a major cause of esotropia, and few existing studies have attempted to demonstrate a correlation between levels of hyperopia and severity of deviation in esotropic patients. For example, from a study of 47 patients with accommodative esotropia onset between the ages of 0.3 to 7.0 years and prescribed glasses for hyperopia between the ages of 1.5 to 9.0 years, 7 had hyperopia measurements of less than +3.00 diopters [D], 29 measured ≥+3.00 D - +5.00 D, and 11 had greater than +5.00 D correction. [10]

Due to the fact that few other studies of similar nature exist, there seems to be a significant gap in the literature with respect to predicting whether the need for corrective surgery in one to six year old children based on severity of hyperopia is possible. This project will attempt to in some way fill that gap.

Research question/Hypotheses/Goals for the study

The research question we sought to answer is: can refractive errors in children with esotropia who are between the ages of two to six years old be used to predict treatment outcomes? Our study is a retrospective review of esotropic children between the ages of 2-6 years old who presented in office between 2008-2010. Data to be collected and analyzed will include: patient age at initial office visit, age of esotropia onset (when available), initial refractive error, initial deviation measurement, final or most recent refractive error, final or most recent deviation measurement, present or absence of accompanying amblyopia, duration of amblyopia treatment and age of surgery (if applicable).

The goal of this study is to determine whether the initial level of hyperopia is a risk factor for further surgery in intermittent exotropia corrective surgery patients between the ages of two to six years.

We hypothesize that children between the ages of two to six years with less severe hyperopia or smaller refractive error will be at increased risk of developing partially accommodative esotropia and will therefore be more likely to require surgical correction.

Materials and Methods

This study is a retrospective review of children between the ages of two to six years who were diagnosed with strabismus between the years of 2008-2010. Inclusion criteria consisted of date of birth between January 1st, 2002, and December 31st, 2008, and diagnosis of strabismus within the patient chart. Excluded from the study were patients with the diagnosis of pseudostrabismus and those whose strabismus was attributed to another medical process or disease.

Data collected and analyzed includes: age in months, initial vision at presentation, length of time patients had amblyopia before surgery, amblyopia treatments and their length of use prior to surgery, preoperative degree of hyperopia, preoperative misalignment measurements, one to two week postoperative alignment measurements, the most up to date hyperopia and alignment measurements, and time since surgery of these most up to date measurements.

Retrospective patient data was collected through the office of Dr. Mark Salevitz, who has operated on thousands of children over the past few decades. 350 patient charts were reviewed. 238 patients were excluded from the study due to multiple factors, including a diagnosis of pseudostrabismus or a loss of follow-up after initial visit. By the end of data collection, 112 patients met the study criteria and data per above was collected and analyzed for each.

The main outcome we focused on for this study was whether or not each patient required surgery for correction of strabismus. Although variables including astigmatism, amblyopia and anisometropia were included in the analysis, the aim of the study was to ascertain the relationship between severity of hyperopia measurements with the need for corrective surgery.

Results/Statistical Analysis

Statistical analysis

Demographic and clinical characteristics were assessed for surgical and non-surgical patients using means, standard deviations for continuous variables and frequencies, proportions for categorical variables. Odds ratios and 95% confidence intervals were estimated using logistic regression to ascertain associations between selective covariates and surgical status (right eye score, left eye score, age (>4 vs $\leq$ 4), astigmatism, amblyopia, anisometropia were assessed as covariates). First, univariate analysis was conducted to ascertain associations between each of the covariates and surgical status separately. Second, all of the covariates were entered into one model to test how well the covariates would predict surgery as a group. The final two models excluded the right eye score and the left eye score respectively. These two models were then stratified by age and astigmatism respectively to assess for confounding. Finally, the above methods were implemented with amblyopia as the primary outcome.

Table 1. Demographic and Clinical Characteristics stratified by Surgical Status

Characteristics	Overall Population n=112	Surgery N=45	No Surgery N=67	P-value[1]
Age (n, %)				0.046
≤ 4	67 (59.8)	35 (52.2)	32 (71.1)	
>4	45 (40.2)	32 (47.8)	13 (28.9)	
Astigmatism (n, %)				0.29
Yes	44 (39.3)	15 (33.3)	29 (43.3)	
No	68 (60.7)	30 (66.7)	38 (56.7)	
Amblyopia (n, %)				0.63
Yes	92 (82.1)	56 (83.6)	36 (80.0)	
No	20 (17.9)	11 (16.4)	9 (20.0)	
Anisometropia (n, %)				0.77
< 1	83 (74.1)	49 (73.1)	34 (75.6)	
≥1	29 (25.9)	18 (26.9)	11 (24.4)	
Right Eye Score (Mean, SD)	3.4 (1.8)	2.92 (1.7)	3.73 (1.8)	0.02
Left Eye Score (Mean, SD)	3.5 (1.8)	3.12 (1.7)	3.82 (1.9)	0.05

[1]P-value calculated via univariate analysis using logistic regression.

Table 1 represents demographic and clinical characteristics stratified by surgical status.

There was a statistically significant difference in this group between surgical and non-surgical patients aged greater than four years (P-value 0.046) with a greater percentage of patients older than four requiring surgery.

Data also indicates with statistical significance that in this group the mean right eye score (p-value 0.02)and left eye score (p-value 0.05) were higher in non-surgical patients. Although not statistically significant, it is important to note the clinical significance of the astigmatism group. In the population, the group with astigmatism who did not require surgery was 10% greater than the group with astigmatism who did not require surgery.

Table 2. Ascertaining the association between selected covariates and Surgery.

Variables	Model 1		Model 2		Model 3		Model 4	
		p-value[1]		p-value[2]		p-value[3]		p-value[4]
	OR (95%CI)[1]		OR (95%CI)[2]		OR (95%CI)[3]		OR (95%CI)[4]	
Right Eye Score	0.76 (0.60, 0.96)	0.02	0.62 (0.32, 1.20)	0.16	0.70 (0.54, 0.91)	0.007	N/A	---
Left Eye Score	0.80 (0.64, 1.00)	0.051	1.14 (0.61, 2.15)	0.67	N/A	---	0.75 (0.59, 0.96)	0.019
Age (n, %)		0.048		0.036		0.034		0.035
	Referent		Referent		Referent		Referent	
4	2.25 (1.01, 5.02)		2.61 (1.06, 6.41)		2.64 (1.07, 6.47)		2.60 (1.06, 6.35)	
4								
Astigmatism		0.29		0.64		0.65		0.58
No	Referent		Referent		Referent		Referent	
Yes	0.66 (0.30, 1.43)		0.80 (0.32, 1.98)		0.81 (0.33, 2.01)		0.78 (0.35, 1.92)	
Amblyopia		0.63		0.88		0.92		0.81
No	Referent		Referent		Referent		Referent	
Yes	0.79 (0.30, 2.08)		0.92 (0.31, 2.71)		0.95 (0.32, 2.78)		0.88 (0.29, 2.56)	
Anisometropia		0.77		0.71		0.64		0.87
	Referent		Referent		Referent		Referent	
< 1	0.88 (0.37, 2.09)		0.82 (0.28, 2.36)		0.80 (0.30, 2.10)		1.08 (0.42, 2.80)	
≥1								

[1]OR (95% CI) and p-values calculated via univariate analysis using Logistic Regression.
[2]OR (95% CI) and p-values calculated using Multiple Logistic Regression adjusting for all other covariates.
[3]OR (95% CI) and p-values calculated using Multiple Logistic Regression excluding the Left eye score adjusting for all other covariates.
[4]OR (95% CI) and p-values calculated using Multiple Logistic Regression excluding the Right Eye Score adjusting for all other covariates.

Table 2 quantifies the association between selected covariates and surgery status.

Model 3, which includes the right eye score and excludes the left eye score, demonstrates that if the right eye score increases by one point, the likelihood of the child needing surgery decreases by 30% (p-value 0.007).

Model 4, which excludes the right eye score and includes the left eye score, shows that for every one point increase in the left eye score there is a decreased likelihood of needing surgery of 25% (p-value 0.019).

The data from both Models 3 and 4 suggests that children less than or equal to four years of age were nearly three times more likely to have surgery compared to children older than four (p-values 0.034 and 0.035, respectively). Astigmatism, amblyopia and anisometropia did not have statistically significant associations to surgery in either model.

Table 3. Ascertaining the association between selected covariates and Surgery stratified by Age Categories.

Variables	Age > 4		Age ≤ 4	
	OR (95% CI)[1]	P-value[1]	OR (95% CI)[1]	P-Value[1]
RIGHT EYE				
Right Eye	0.66 (0.42, 1.03)	0.07	0.67 (0.47, 0.94)	0.022
Astigmatism		0.20		0.11
No	Referent		Referent	
Yes	2.84 (0.57, 14.3)		0.35 (0.09, 1.27)	
Amblyopia		0.04		0.19
No	Referent		Referent	
Yes	0.12 (0.02, 0.91)		2.53 (0.61, 10.4)	
Anisometropia		0.13		0.32
< 1	Referent		Referent	
≥1	3.70 (0.69, 19.8)		0.51 (0.14, 1.89)	
LEFT EYE				
Left Eye	0.68 (0.45, 1.06)	0.088	0.75 (0.55, 1.01)	0.066
Astigmatism		0.28		0.13
No	Referent		Referent	
Yes	2.41 (0.49, 11.9)		0.38 (0.11, 1.33)	
Amblyopia		0.037		0.24
No	Referent		Referent	
Yes	0.12 (0.01, 0.88)		2.27 (0.57, 9.01)	
Anisometropia		0.09		0.52
< 1	Referent		Referent	
≥1	4.31 (0.78, 19.4)		0.67 (0.19, 2.33)	

[1]OR (95% CI) and p-values calculated using Multiple Logistic Regression adjusting for all other covariates stratified by age categories.

In Table 3 we stratified by age ≤ 4 or age > 4 and compared right eye data to left eye data.

Right Eye:

In only children older than four there was a decreased likelihood of surgery if right eye scores increased by 1.0 point (p-value 0.022). Children older than four with amblyopia were almost 90% less likely to have surgery (p-value 0.04).

Left Eye:

In both age groups there was a decreased risk of surgery for every one 1.0 point increase in left eye score. Children older than 4 with amblyopia in the left eye were also almost 90% less likely to need surgery (p-value 0.037).

Age was considered a bias in this analysis because the associations of astigmatism, amblyopia and anisometropia relative to surgery were completely opposite.

Table 4. Ascertaining the association between selected covariates and Surgery stratified by Astigmatism status.

Variables	No Astigmatism		Astigmatism	
	OR (95% CI)[1]	P-value[1]	OR (95% CI)[1]	P-Value[1]
RIGHT EYE				
Right Eye	0.54 (0.36, 0.82)	0.004	0.89 (0.62, 1.29)	0.55
Age Categories		0.006		0.83
>4	Referent		Referent	
≤ 4	7.56 (1.8, 32.0)		1.15 (0.29, 4.44)	
Amblyopia		0.48		0.22
No	Referent		Referent	
Yes	1.59 (0.43, 5.86)		0.19 (0.01, 2.63)	
Anisometropia		0.67		0.59
< 1	Referent		Referent	
≥1	0.73 (0.17, 3.07)		1.45 (0.37, 5.64)	
LEFT EYE				
Left Eye	0.59 (0.41, 0.87)	0.008	0.94 (0.67, 1.32)	0.71
Age Categories		0.008		0.83
>4	Referent		Referent	
≤ 4	6.4 (1.61, 25.5)		1.15 (0.29, 4.56)	
Amblyopia		0.56		0.21
No	Referent		Referent	
Yes	1.46 (0.41, 5.2)		0.18 (0.01, 2.52)	
Anisometropia		0.75		0.55
< 1	Referent		Referent	
≥1	1.25 (0.30, 5.19)		1.50 (0.38, 5.78)	

[1]OR (95% CI) and p-values calculated using Multiple Logistic Regression adjusting for all other covariates stratified by Astigmatism status.

Table 4 ascertains the association between selected covariates and surgery, stratified by astigmatism status.

Right eye with no astigmatism:

For patients with no astigmatism, when right eye scores increased by 1.0 points, the likelihood of surgery decreased by 40%. Patients aged four years or younger with no astigmatism were more likely to require surgery than patients older than four years. Both right eye scores and age were statistically significant (p values: 0.004 and 0.006, respectively).

Right eye with astigmatism:

For patients with astigmatism, when right eye scores increased by 1.0 point, the likelihood of surgery decreased by 11%. Patients aged four years or younger who had astigmatism had a 15% increased likelihood of surgery over patients older than four years.

Left eye with no astigmatism:

For patients with no astigmatism, when left eye scores increased by 1.0 point, the likelihood of surgery decreased by 41%. Patients aged four years or younger with no astigmatism were more likely to require surgery than patients older than four years. Both left eye scores and age were statistically significant (p values: 0.008 and 0.008, respectively).

Left eye with astigmatism:

For patients with astigmatism, when left eye scores increased by 1.0 point, the likelihood of surgery decreased by 6%. Patients aged four years or younger who had astigmatism had a 15% increased likelihood of surgery over patients older than four years.

Table 5. Ascertaining the association between selected covariates and Amblyopia.

Variables	Model 1	p-value[1]	Model 2	p-value[2]	Model 3	p-value[3]	Model 4	p-value[4]
	OR (95%CI)[1]		OR (95%CI)[2]		OR (95%CI)[3]		OR (95%CI)[4]	
Right Eye Score	1.06 (0.80, 1.41)	0.65	2.53 (0.54, 11.8)	0.24	1.09 (0.81, 1.49)	0.55	N/A	---
Left Eye Score	1.06 (0.81, 1.39)	0.64	0.44 (0.10, 1.89)	0.27	N/A	---	1.04 (0.78, 1.39)	0.76
Age (n, %)		0.98		0.38		0.39		0.36
	Referent		Referent		Referent		Referent	
4	0.99 (0.36, 2.65)		1.64 (0.53, 5.10)		1.64 (0.53, 5.11)		1.68 (0.54, 5.25)	
4								
Astigmatism		0.022		0.026		0.028		0.028
No	Referent		Referent		Referent		Referent	
Yes	4.56 (1.24, 16.6)		4.87 (1.20, 19.7)		4.81 (1.18, 19.6)		4.80 (1.18, 19.5)	
Anisometropia		0.044		0.046		0.064		0.069
< 1	Referent		Referent		Referent		Referent	
≥1	8.31 (1.06, 65.2)		17.2 (1.04, 282.8)		7.21 (0.89, 58.2)		6.98 (0.85, 57.0)	

[1]OR (95% CI) and p-values calculated via univariate analysis using Logistic Regression.
[2]OR (95% CI) and p-values calculated using Multiple Logistic Regression adjusting for all other covariates.
[3]OR (95% CI) and p-values calculated using Multiple Logistic Regression excluding the Left eye score adjusting for all other covariates.
[4]OR (95% CI) and p-values calculated using Multiple Logistic Regression excluding the Right Eye Score adjusting for all other covariates.

Table 5 ascertains the association between selected covariates and amblyopia.

Model 3 and 4 data indicates there is no association between amblyopia and left or right eye scores. Although not significantly significant, age less than or equal to four years appears to have some clinical significance with respect to amblyopia as these patients were found to be 64% (model 3) and 68% (model 4) more likely to have amblyopia. Patients with astigmatism were almost five times more likely to have amblyopia than those without astigmatism (p-value 0.028). Patients with anisometropia were almost seven times more likely to have amblyopia than those without anisometropia.

Discussion

Limitations to this study include a small sample size and the fact that it was a retrospective chart review. It should also be noted that although age of the patient was found to be statistically significant in several of our models, surgeon preference was not considered.

Future Directions

Because of the impact strabismus can have on the development of a child, it is critical to recognize and correct it as early as possible. Correcting too much, too early (surgery at too young an age, for example), however, can impede a child's physical development and increase the likelihood of long-term miscommunication between the eyes, or the outside world, and the child's brain. This project will hopefully give a small bit of insight into how one group of children – young children with significant levels of hyperopia and intermittent esotropia – can be expected to respond to non-surgical intervention. Having this insight may help the child, parents, and physician have a clearer understanding of expectations throughout the corrective process, which will hopefully lead to increased compliance and better outcomes.

Conclusions

This small study indicates that, as we hypothesized, patients between the ages of two and six years who have acquired esotropic strabismus are at increased risk of requiring corrective surgery as the measure of hyperopia decreases. The mean measures of hyperopia in our patient population were 3.4 diopters in the right eye and 3.5 diopters in the left eye. Patients who required corrective surgery had mean right and left eye measurements of 2.92 and 3.12 diopters, respectively, while measurements in the non-surgical group were 3.73 (right) and 3.82 (left) diopters. This difference was statistically significant (p-values 0.02 right eye and 0.05 left eye).

Age was also an important indicator for whether or not the patient required corrective surgery. The statistical analysis showed that patients who were four years of age or younger were nearly three times more likely to have surgery compared to patients older than four years. While this is what the data shows, the surgeon's preferences for surgery appropriate age and/or the duration of attempted pre-surgical treatment of the strabismus must be considered along with the data.

It should also be noted that when ascertaining the association between measurements of the degree of astigmatism, amblyopia and anisometropia and surgery, we did not find a statistically significant association.

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