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Laterality of Amblyopia

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Abstract

Purpose—To determine the frequency of right versus left eyes with unilateral amblyopia among children <18 years of age

Design—Analysis of data collected in randomized clinical trials conducted by the Pediatric Eye Disease Investigator Group.

Methods—The laterality of the amblyopic eye was analyzed in 2,635 subjects <18 years of age who participated in 9 multicenter prospective randomized treatment trials. Eligibility criteria for these clinical trials included unilateral amblyopia associated with strabismus, anisometropia or both, with visual acuity between 20/40 and 20/400. Logistic regression was used to assess the association of baseline and demographic factors with the laterality of amblyopia.

Results—Among subjects with anisometropic amblyopia (with or without strabismus), amblyopia was present more often in left than right eyes, with a relative prevalence of 59% in left eyes (95% confidence interval 57% to 62%, $p < 0.001$ from a test of proportion = 50%). However, among subjects with strabismic only amblyopia there was no laterality predilection (relative prevalence of 50% in left eyes, 95% confidence interval 47% to 54%, $P = 0.94$).

Conclusion—Anisometropic amblyopia, with or without strabismus, occurs more often in left eyes than right eyes. This finding of amblyopia laterality may be related to microtropia, sighting

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The respective institutional review boards approved the protocol and Health Insurance Portability and Accountability Act-compliant informed consent forms. The protocol and informed consent forms were approved by the institutional review boards for each of the named authors, and the parent of each study patient gave written informed consent. Study oversight was provided by an independent data and safety monitoring committee. The studies from which these data were obtained are registered at www.clinicaltrials.gov, identifiers NCT00000170, NCT00094744, NCT00094679, NCT00094692, NCT00094614, NCT00091923, NCT00315198, NCT00315302, and NCT00315328.

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dominance or other forms of ocular dominance, developmental or neurological factors, and/or laterality in the development of refractive error.

Introduction

Among individuals with amblyopia, reduced visual acuity is typically present in one eye. Several retrospective reports suggest that amblyopia occurs more often in left eyes (Table 1).¹⁻⁵ In this report we examine the laterality of amblyopia among children <18 years of age enrolled in prospective amblyopia studies conducted by the Pediatric Eye Disease Investigator Group (PEDIG).

Methods

The patient population for this report was drawn from 9 randomized multicenter clinical trials.⁶⁻¹³ The protocols are available on the PEDIG website (www.pedig.net). Two thousand six hundred and thirty-five subjects, ranging in age from 2 to 17 years, with unilateral amblyopia (20/40 and 20/400, logMAR 0.3 and 1.3) associated with strabismus, anisometropia or both combined were enrolled. Specific eligibility criteria varied by study. For each patient, amblyopia was classified by presumptive cause into one of three categories. *Strabismic amblyopia* required the presence of (1) either a heterotropia at distance and/or near fixation or a history of strabismus surgery (or botulinum toxin injection), and (2) refractive error not meeting the criteria below for combined mechanism amblyopia. *Refractive/anisometropic amblyopia* (referred to subsequently as *anisometropic amblyopia without strabismus*) required the presence of anisometropia ≥ 0.50 D of spherical equivalent or ≥ 1.50 D difference in astigmatism in any meridian which persisted after at least 4 weeks of spectacle correction, with no measurable heterotropia at distance or near fixation. Eligibility criteria specified that the amblyopic eye be the more hypermetropic eye. *Combined mechanism amblyopia* (referred to herein as *anisometropic amblyopia with strabismus*) required the presence of (1) either a heterotropia at distance and/or near fixation or a history of strabismus surgery (or botulinum toxin injection), and (2) anisometropia ≥ 1.00 D spherical equivalent or ≥ 1.50 D difference in astigmatism in any meridian, which persisted after at least 4 weeks of spectacle correction.

Statistical methods

The proportion of subjects with amblyopia in their left eyes and the corresponding 95% confidence interval was calculated overall and in subgroups based on baseline factors including cause of amblyopia, age at randomization (<7 years old versus 7 to <18 years old), race (white versus non-white), and severity of amblyopia (amblyopic eye visual acuity 20/100 or better versus 20/125 or worse). The analysis consisted of an exact binomial test evaluating the null hypothesis that the proportion of cases with the left eye affected was 0.50. A multivariate logistic regression analysis was used to explore whether amblyopic eye laterality differed with respect to the baseline factors above while adjusting for the other baseline factors (with cause of amblyopia and race as categorical variables, and age and severity of amblyopia as continuous variables).

Among subjects with anisometropic amblyopia with or without strabismus, the multivariate logistic model was repeated to include the amount of anisometropia (continuous) and the amount of hyperopia in the amblyopic eye (continuous), in addition to age, race, and amblyopic eye visual acuity.

Results

Among 2635 subjects with unilateral amblyopia, 56.6% of amblyopic eyes were left eyes (95% confidence interval 54.7% to 58.5%, $P < 0.001$ from test of proportion = 50%, Table 2). Laterality was associated with the presence of anisometropic amblyopia with or without strabismus ($P < 0.001$). Among subjects with anisometropic amblyopia (747 subjects with strabismus and 1071 without strabismus), amblyopia was present more often in left than right eyes, with a relative prevalence of 59% in left eyes (95% confidence interval 56% to 62%, $p < 0.001$ from a test of proportion = 50%), whereas among subjects with strabismic only amblyopia ($N=817$) there was no laterality predilection (relative prevalence of 50% in left eyes, 95% confidence interval 47% to 54%, $P=0.94$). There was no significant difference in the laterality of the anisometropic patients when comparing those with to those without strabismus (61% versus 59%, $P = 0.68$).

Among subjects with anisometropic amblyopia with or without strabismus, there was no apparent relationship of laterality with age ($P = 0.33$), race ($P = 0.96$), or amblyopia severity ($P = 0.66$). The degree of anisometropia was not associated with laterality ($P=0.47$); however, there was an increased likelihood of the left eye being amblyopic with increasing hypermetropia in the amblyopic eye ($P < 0.001$, Table 2).

Discussion

Among subjects with anisometropic amblyopia with or without strabismus, we found left eyes to be amblyopic in 59% of subjects enrolled in our series of amblyopia treatment trials. These prospective data are supportive of five retrospective reports of amblyopia laterality, all of which found amblyopia to be more common in left eyes (Table 1).¹⁻⁵ Contrary to an earlier finding by Coren and Duckman of significant left-eye laterality in 147 of 258 (57%) patients with pure strabismic amblyopia,² we found no laterality in subjects with pure strabismic amblyopia, with left eye amblyopic in 50% of subjects. However, the current PEDIG study was prospective and included more than three times the number of subjects with strabismic amblyopia ($n = 817$ vs. $n = 258$) compared with Coren and Duckman.²

What might be the cause of the left eye laterality of amblyopia among patients with anisometropia? There seem to be at least four possible mechanisms: microtropia, sighting or other forms of ocular dominance, developmental and/or neurologic effects, and refractive error development. These mechanisms might cause the laterality bias by causing suppression in one eye thereby leading to amblyopia.

Microtropia is of interest because it too has a left eye laterality. The associated visual deficits (amblyopia and central suppression) are reported to occur in the left eye of 65 to 100% of microtropic subjects evaluated in four non-PEDIG studies (combined $N=105$).¹⁴⁻¹⁷ Microtropia is also commonly associated with anisometropic amblyopia. It was found to be present in 45 to 98% of subjects in four studies of anisometropic amblyopia.^{15, 16, 18, 19} Three of these studies also noted the left eye laterality of anisometropic amblyopia.^{15, 16, 20} Helveston and von Noorden proposed 40 years ago that all subjects with anisometropic amblyopia are microtropes.¹⁶ Recent findings using sensitive instrumentation for alignment detection have found very small misalignments in some patients diagnosed with anisometropic amblyopia lending support to their hypothesis.²¹ (Hunter, *IOVS* 2008; 43: ARVO E-abstract 2829) In our study it is possible that some of the “pure” anisometropic cases were classified as orthotropic because their angle of strabismus was too small to detect clinically. An argument against a role for microtropia in causing laterality is the lack of laterality among children with strabismus. However, microtropia typically is associated with peripheral fusion, which may make the performance of these individuals different from

those with larger angles of strabismus who lack such fusion. We do not have sufficient alignment data to properly explore the effect of microtropia compared with larger angle strabismus.

It is uncertain whether the anisometropia, the microtropia, or the amblyopia came first in these subjects. Suggestive of microtropia as the precipitating factor is the postulated genetic origin of microtropia.^{18, 22} In this scenario, the anisometropic amblyopia laterality arises from a hereditary microtropia with preferential foveal suppression in the left eye. Conversely, it has been proposed that the microtropia develops from a pre-existing anisometropia which leads to a foveal scotoma.^{15, 23} (p. 327)

A second explanation for the laterality could be from a form of ocular “dominance” in which one eye is preferred over the other.^{24, 25} There are a variety of means of assessing ocular dominance, the most widely being “sighting” dominance.^{25, 26} Assessment of sighting dominance is determined by which eye is used to sight through a telescope or to align objects. Using sighting techniques the right eye of normal subjects is preferred at least 60% of the time.²⁵

It has been proposed that sighting dominance may be a mild form of interocular suppression that prevents diplopia arising from the image disparity present in normal stereoscopic vision.²³(p. 294),²⁵ Objective physiologic support for a cortical imbalance associated with sighting dominance has been seen with functional magnetic resonance imaging (fMRI). In a study of sighting dominance Rombouts and coworkers found that the dominant eye of normal subjects activated a significantly larger area of primary visual cortex than the non-dominant eye.²⁷ The cortical activation imbalances could be representative of unilateral suppression. It is our hypothesis that in some children the normal mild suppression of ocular sighting dominance is exaggerated due to yet unidentified factors. This then results in foveal suppression and subsequently amblyopia.

Several cautions about the sighting dominance hypothesis are warranted. Sighting dominance and visual acuity do not necessarily correlate in non-amblyopic patients.²⁸ Furthermore, we did not measure sighting dominance in this study, nor do we know which eye might have been dominant prior to the development of the anisometropic amblyopia.

A third possibility for the laterality found in amblyopia might be developmental and/or neurological, either related to sighting dominance or other unknown factors. There is evidence that sighting dominance may have a genetic basis.²⁹⁻³² In addition, a number of other disorders exhibit laterality. Duane retraction syndrome patients demonstrated left eye laterality in two studies of 66%³³ and 74%,³⁴ respectively. Studies of children with Williams-Beuren Syndrome³⁵ and autism³⁶ exhibit a left eye sighting dominance. In another study adult male, but not female, schizophrenics exhibited significantly increased frequency of left eye sighting dominance compared to controls.³⁷ (Males normally have higher rates of right eye laterality than females.³⁸⁻⁴⁰) Left eye laterality was also significantly more likely to occur in male subjects with migraine than male controls, but not in female subjects.⁴¹

A fourth possibility for the laterality in anisometropic amblyopia might be related to the mechanism of emmetropization. Such a laterality effect has been reported in studies of anisomyopia development. In separate studies, the right eye⁴² or the sighting dominant eye³⁸ was found to have a small, but significantly longer axial length and greater myopia than left or nondominant eyes, respectively. A third study found a “tendency” toward greater spherical myopia in the right eye.⁴³ Although these are studies of anisomyopia development, the anisometropia is in the same direction as we have found in this study which included only hypermetropic eyes.

For the mechanisms based on microtropia or sighting dominance, how might foveal suppression and amblyopia lead to anisometropia? Perhaps the sensory changes retard the normal emmetropization of the hypermetropic non-dominant eye, leading to development of anisometropia. Retinal defocus or blur is known to regulate emmetropization.⁴⁴ Anisometropia may develop because emmetropization is independent in the two eyes,⁴⁵ ultimately resulting in anisometropic amblyopia in the more hypermetropic eye.⁴⁶

Finally, could the left-sided laterality in anisometropic amblyopia be an artifact of testing order? The visual acuity testing protocols for PEDIG studies specified that the right eye be tested first.^{47, 48} Therefore, the left eye preponderance could be an artifact due to test fatigue in the left eye. However, such an artifact seems unlikely since studies of testability of normal children using the PEDIG visual acuity protocols found no evidence of either a fatigue effect or its opposite, a learning effect.⁴⁷⁻⁴⁹

In summary anisometropic amblyopia, with or without strabismus, is found significantly more often among left eyes. This finding may be related to microtropia, sighting dominance or other forms of eye dominance, neurological factors or factors associated with refractive error development.

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Table 1

Studies of Amblyopia Laterality

Study	N	Type	Left Eye Prevalence (95% Confidence Interval)
Cole 1959 ¹	527	M	58% (53% to 62%)
Coren 1975 ²	258	S	57% (51% to 63%)
Hopkisson 1982 ⁵	379	M	53% (48% to 58%)
Attebo 1998 ³	118	M	53% (44% to 63%)
Woodruff 1994 ⁴	164	A	64% (56% to 71%)
	262	C	56% (50% to 62%)
	535	S	53% (49% to 57%)
Total	2243	-	56% (54% to 58%)

M= Included cases of anisometropic amblyopia and cases of strabismic amblyopia, A = Anisometropic amblyopia, S= Strabismic amblyopia, C = Combined anisometropic and strabismic amblyopia

Table 2

Laterality of Amblyopia Stratified by Patient Factors Among Patients with Anisometropic Amblyopia With or Without Strabismus

	N	Left Eye Percentage	P-Value ^a
Race			0.96
White	1533	60%	
Non-White	285	58%	
Age at Enrollment			0.33
<5 years old	470	61%	
5 to <7 years old	815	58%	
7 to <9 years old	211	60%	
9 to <12 years old	213	60%	
12 to <15 years old	80	63%	
15 to <18 years old	29	62%	
Visual Acuity in the Amblyopic Eye			0.66
20/100 or better (≥48 letters)	1448	59%	
20/125 or worse (≤47 letters)	370	61%	
Amount of Hypermetropia in Amblyopic Eye			<0.001
<+2.00D	180	46%	
+2.00 to <+4.00	390	55%	
≥+4.00	1248	63%	
Degree of Anisometropia			0.47†
<+1.00D	333	55%	
+1.00 to <+2.00	631	59%	
+2.00 to <+3.00	337	59%	
+3.00 to <+4.00	248	61%	
≥+4.00	269	64%	

^aP-values from a multivariate logistic regression analysis evaluating the association of amblyopic eye predominance with race, age at enrollment, amblyopic eye acuity, amblyopic eye refractive error, and degree of anisometropia. All covariates were included in the model as continuous variables other than race.