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Association Between Neonatal Retinal Hemorrhage and Refractive Outcomes in Early Childhood

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Abstract: ***Objective: To systematically evaluate the association between neonatal retinal hemorrhage and refractive outcomes in early childhood, with a particular focus on astigmatism and astigmatic axis orientation. Methods: This study was a retrospective cohort study. 429 neonates who underwent fundus screening between September 2020 and September 2021 were retrospectively reviewed. Multivariable linear regression models were used to assess associations between neonatal retinal hemorrhage and continuous outcomes, including LogMAR visual acuity and cylinder power. Multivariable logistic regression models were applied for binary outcomes, including clinically significant astigmatism and oblique astigmatism. All models were adjusted for predefined covariates. Results: Our results demonstrated that neonatal retinal hemorrhage, whether analyzed as a binary exposure or further stratified by hemorrhage severity, was not significantly associated with childhood visual acuity, astigmatism magnitude, clinically significant astigmatism, or the risk of oblique astigmatism. Conclusion: The neonatal retinal hemorrhage was not associated with adverse visual or refractive outcomes in childhood.***

Keywords: Neonatal retinal hemorrhage, Refractive, Fundus screening.

1. Introduction

Neonatal retinal hemorrhage (RH) is one of the most frequently observed ocular abnormalities in the perinatal period, yet its long-term implications for ocular development remain incompletely understood [1] [2]. With the widespread implementation of wide-field fundus imaging and neonatal ocular screening programs, RH has been increasingly recognized in otherwise healthy term infants [3] [4]. Reported incidence rates vary widely across populations and study designs, ranging from a few percent to over 20%, largely depending on screening timing and methodology [3] [5]. Previous studies have consistently demonstrated a strong association between RH and mode of delivery, with vaginal delivery—particularly when assisted by vacuum extraction or forceps—conferring a substantially higher risk compared with cesarean section [3] [4] [6]. In contrast, most neonatal RHs resolve spontaneously within the first weeks of life and have traditionally been regarded as transient, self-limited events [5]. However, this assumption is primarily based on observations of short-term fundus resolution rather than systematic evaluation of long-term visual or refractive outcomes [7].

Early childhood represents a critical period of rapid ocular growth and refractive maturation, during which emmetropization plays a central role in shaping visual development [8] [9].

The emmetropization process relies on visually guided feedback mechanisms that regulate ocular growth and refractive state [10]. Astigmatism is common in infancy and early childhood and is clinically relevant given its association with amblyopia and abnormal visual development [11]. Importantly, accumulating evidence suggests that the axis of astigmatism may be prognostically informative: oblique astigmatism has been associated with a substantially higher prevalence of amblyopia in childhood [12] [13]. Moreover, experimental and translational work indicates that astigmatic defocus can interact with emmetropization, supporting the rationale for evaluating astigmatic magnitude and axis orientation as sensitive markers of disrupted refractive development [14] [15].

Despite growing knowledge regarding the epidemiology and perinatal determinants of neonatal RH, evidence linking RH to subsequent refractive development remains scarce [2] [7].

Most existing studies have focused on RH incidence, obstetric risk factors, and short-term natural history [6], while relatively few have examined refractive outcomes later in childhood [7]. In addition, RH severity stratification and its potential dose–response relationship with later ocular outcomes have been inconsistently addressed across studies [4]. Consequently, whether neonatal RH has any measurable impact on visual acuity, refractive error, or astigmatic patterns during childhood remains largely unexplored.

Perinatal confounders may independently influence both RH occurrence and refractive development.

Factors such as mode of delivery, birth weight, and perinatal distress are well-established correlates of RH [3] [4] [6], and may also influence refractive development through distinct biological pathways, including preterm-related refractive sequelae. Failure to adequately account for these confounders may obscure or falsely suggest associations between RH and later refractive status. In addition, emerging evidence suggests that even after clinical resolution of birth-related RH, subtle differences in foveal structure may persist, highlighting the need for careful long-term phenotyping beyond fundus appearance alone.

Against this background, the present study aimed to systematically evaluate the association between neonatal retinal hemorrhage and refractive outcomes in early childhood, with a particular focus on astigmatism and astigmatic axis orientation. Specifically, we sought to: (1) characterize perinatal features and RH distribution; (2) compare refractive parameters among children with no RH, mild RH, and extensive RH while controlling for relevant confounders; and (3) examine whether neonatal RH is associated with an increased risk of oblique astigmatism.

2. Method

2.1 Study Design and Population

This study was a retrospective cohort study conducted at Yuyao Maternal and Child Health Care Hospital, China. The study was based on a routinely implemented neonatal fundus screening program and its subsequent refractive follow-up database. All data were derived from electronic medical records generated during routine clinical care. Neonates who underwent fundus screening between September 2020 and September 2021 were retrospectively reviewed.

A total of 448 neonates were initially identified. During data cleaning, 18 cases with missing key information and one case of congenital cataract were excluded. Given that retinopathy of prematurity (ROP) may independently affect retinal structure and subsequent refractive development, one infant diagnosed with ROP was further excluded to minimize potential confounding. The final study cohort comprised 429 children, who were categorized according to neonatal fundus examination findings. (Consent from parent) (Shown in Figure 1)

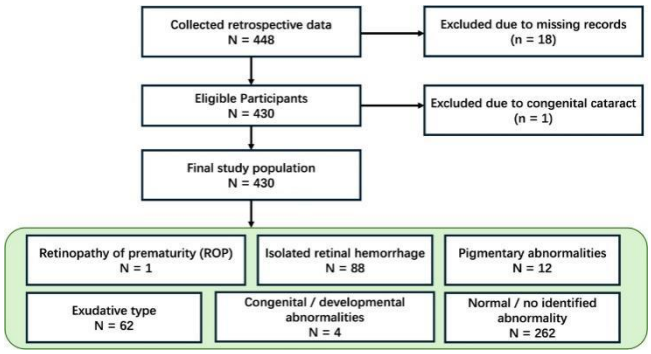

Figure 1: Flowchart of Study Population and Fundus Findings

2.2 Inclusion and Exclusion Criteria

2.2.1 Inclusion criteria

Participants were included if they met all of the following criteria:

- Underwent neonatal fundus examination as part of the hospital's routine newborn screening program;
- Completed at least one subsequent refractive assessment during childhood;
- Had a gestational age at birth of ≥31 weeks, including both term infants and a subset of preterm infants.

2.2.2 Exclusion criteria

Participants were excluded if they met any of the following criteria:

- Presence of congenital ocular diseases that could independently influence visual function or refractive development, including congenital cataract and congenital glaucoma;
- Diagnosis of retinopathy of prematurity (ROP);
- Incomplete clinical or follow-up data that precluded analysis of the primary outcomes.

2.3 Neonatal Fundus Examination and Retinal Hemorrhage Classification

All neonates underwent fundus screening according to the hospital's standardized neonatal fundus screening protocol. The timing of the initial examination was determined based on gestational age and birth weight: term infants were generally examined within 0–4 days after birth, whereas preterm infants were examined according to corrected gestational age in accordance with national screening recommendations. In the present cohort, the actual timing of fundus examination was primarily between 2.5 and 3.6 days after birth, with an allowed examination window of ≤7 days.

Pupil dilation was achieved using compound tropicamide eye drops, followed by topical anesthesia once adequate dilation was obtained. Fundus imaging was performed using a wide-field digital retinal imaging system (Nautilus RS-B002, Guangzhou Nuoxinde Medical Technology Co., Ltd., China). Systematic images of the posterior pole, optic disc, macula, and multiple peripheral quadrants were acquired. All examinations were conducted under close monitoring, and no serious screening-related complications were observed.

Based on fundus images and clinical records, neonatal retinal findings were classified into predefined categories, including simple retinal hemorrhage, exudative/inflammatory changes, pigmentary abnormalities, congenital or developmental abnormalities, and normal or no definite abnormality. For analyses focusing on hemorrhagic severity, retinal hemorrhage was further categorized as mild or extensive. This classification was determined according to imaging characteristics such as the extent of hemorrhage, the number of involved quadrants, and involvement of the posterior pole, and was made by experienced ophthalmologists based on routine clinical judgment.

2.4 Refractive Assessment and Outcome Definitions

Refractive assessments during childhood were performed when children were aged between 3 and 4 years, under natural pupil conditions in a dimly lit room using a Spot Vision Screener (Welch Allyn VS100). Refractive parameters were recorded in minus-cylinder notation according to routine clinical protocols. In accordance with the screening procedure, refractive measurements were typically obtained three times per eye, and the recorded average values were used for analysis.

The primary refractive outcomes included cylinder power (astigmatism) as a continuous variable, LogMAR visual acuity, and clinically significant astigmatism, defined as a cylinder power of ≥1.00 diopter (D). Astigmatism severity was further categorized as none (0 D), mild (0–<1.00 D), moderate (1.00–<2.00 D), or high (≥2.00 D).

Astigmatism axis orientation was classified as with-the-rule (0°–30° or 150°–180°), against-the-rule (60°–120°), or oblique (30°–60° or 120°–150°). Age at refractive assessment was recorded as a continuous variable and included as a covariate in all multivariable analyses.

2.5 Covariates

Potential confounding variables were selected a priori based on clinical relevance and previous literature. These included gestational age, birth weight, sex, mode of delivery, perinatal conditions, age at fundus examination, and age at refractive assessment. All covariates were incorporated into multivariable regression models to evaluate the independent association between neonatal retinal hemorrhage and refractive outcomes.

2.6 Statistical Analysis

Left and right eyes were analyzed separately to avoid intra-subject correlation between fellow eyes and to ensure robustness of model estimates without introducing more complex modeling assumptions. Continuous variables were summarized as mean ± standard deviation, and categorical variables as counts and percentages. Group comparisons were performed using appropriate parametric or non-parametric tests depending on data distribution.

Multivariable linear regression models were used to assess associations between neonatal retinal hemorrhage and continuous outcomes, including LogMAR visual acuity and cylinder power. Multivariable logistic regression models were applied for binary outcomes, including clinically significant astigmatism and oblique astigmatism. All models were adjusted for predefined covariates.

All statistical analyses were conducted using R software (R Foundation for Statistical Computing, Vienna, Austria). All tests were two-sided, and a P value < 0.05 was considered statistically significant.

3. Result

3.1 Study Population and Group Classification

A total of 429 children who completed both neonatal fundus examination and subsequent refractive follow-up were included in the final analysis. Based on neonatal fundus findings, participants were categorized into three groups: normal or no definite abnormality, exudative/inflammatory changes, and simple retinal hemorrhage. Among infants with retinal hemorrhage, further subgroup analyses were conducted according to hemorrhage severity, classified as mild hemorrhage or extensive hemorrhage.

Results were analyzed in two sequential stages. First, visual and refractive outcomes were compared across neonatal fundus categories. Second, subgroup analyses were performed to evaluate associations between hemorrhage severity and visual outcomes. Left and right eyes were analyzed separately throughout the study.

3.2 Baseline Characteristics by Neonatal Fundus Findings

In both left- and right-eye analyses, no significant differences were observed among neonatal fundus categories with respect to birth weight, gestational age, gender, prematurity, singleton or multiple birth, oxygen exposure, abnormal Apgar scores, maternal comorbidities (including gestational hypertension, diabetes mellitus, and anemia), premature rupture of membranes, group B streptococcal infection, or thyroid dysfunction (all P > 0.05) (Shown in Table 1).

Table 1: Baseline Characteristics of Left Eyes Stratified by Fundus Subtypes.

Variable	Level	Normal / No identified abnormality	Exudative type	Isolated hemorrhagic type	Statistic	P.value
		N = 291	*N* = 47	*N* = 71		
birth weight(g)		3.16 ± 0.54	3.16 ± 0.43	3.19 ± 0.55	0.577	0.75
Gestational age (weeks)		38.72 ± 1.85	39.08 ± 1.35	39.15 ± 1.52	4.034	0.13
gender					2.633	0.27
	male	146 (50.2%)	26 (55.3%)	43 (60.6%)		
	female	145 (49.8%)	21 (44.7%)	28 (39.4%)		
Preterm birth					0.438	0.80
	Preterm birth	46 (15.8%)	7 (14.9%)	9 (12.7%)		
	Full-term birth	245 (84.2%)	40 (85.1%)	62 (87.3%)		
Plurality					4.257	0.12
	Singleton	275 (94.5%)	44 (93.6%)	71 (100%)		
	Multiple birth	16 (5.5%)	3 (6.4%)			
Mode of Delivery					36.291	0.00
	Vaginal Delivery	182 (62.5%)	28 (59.6%)	70 (98.6%)		
	Cesarean section	109 (37.5%)	19 (40.4%)	1 (1.4%)		
Forceps-assisted delivery					6.290	0.04
	Forceps-assisted	2 (0.7%)	2 (4.3%)	3 (4.2%)		
	No forceps	289 (99.3%)	45 (95.7%)	68 (95.8%)		
Oxygen therapy					3.243	0.20
	Yes	18 (6.2%)		5 (7%)		
	No	273 (93.8%)	47 (100%)	66 (93%)		
Apgar Score					1.070	0.59
	Normal	285 (97.9%)	47 (100%)	70 (98.6%)		
	Abnormal	6 (2.1%)		1 (1.4%)		
Maternal anemia					3.047	0.22
	Yes	279 (95.9%)	45 (95.7%)	71 (100%)		
	No	12 (4.1%)	2 (4.3%)	NA		
Meconium-stained amniotic fluid					8.830	0.18
	No	282 (96.9%)	44 (93.6%)	65 (91.5%)		
	Grade I	1 (0.3%)	1 (2.1%)	2 (2.8%)		
	Grade II	1 (0.3%)	1 (2.1%)	2 (2.8%)		
	Grade III	7 (2.4%)	1 (2.1%)	2 (2.8%)		
Maternal syphilis during pregnancy					2.729	0.26
	Yes	6 (2.1%)	2 (4.3%)			
	No	285 (97.9%)	45 (95.7%)	71 (100%)		
Fetal distress					0.989	0.61
	Yes	7 (2.4%)	2 (4.3%)	3 (4.2%)		
	No	284 (97.6%)	45 (95.7%)	68 (95.8%)		
Premature rupture of membranes (PROM)					0.886	0.64
	Yes	18 (6.2%)	2 (4.3%)	6 (8.5%)		
	No	273 (93.8%)	45 (95.7%)	65 (91.5%)		
Group B Streptococcus (GBS)					0.061	0.97
	Yes	27 (9.3%)	4 (8.5%)	7 (9.9%)		
	No	264 (90.7%)	43 (91.5%)	64 (90.1%)		
Gestational hypertension					1.394	0.50
	Yes	15 (5.2%)	1 (2.1%)	2 (2.8%)		
	No	276 (94.8%)	46 (97.9%)	69 (97.2%)		
Gestational diabetes mellitus (GDM)					0.006	1.00
	Yes	57 (19.6%)	9 (19.1%)	14 (19.7%)		
	No	234 (80.4%)	38 (80.9%)	57 (80.3%)		
thyroid function					0.477	0.79
	Normal	271 (93.1%)	45 (95.7%)	66 (93%)		
	Abnormal	20 (6.9%)	2 (4.3%)	5 (7%)		

However, mode of delivery differed significantly among the fundus categories. In the left-eye analysis, the proportion of vaginal delivery was significantly higher in the simple retinal hemorrhage group compared with the simple retinal hemorrhage group showing a markedly higher rate of vaginal delivery (overall P < 0.001), and the use of forceps-assisted delivery also differed significantly among the three fundus categories in the left-eye analysis (P = 0.04). In the right-eye analysis, a similarly higher proportion of vaginal delivery was observed in the simple hemorrhage group (P < 0.001), whereas no significant difference in forceps use was detected among the three groups (P = 0.36). Given these findings, mode of delivery was included as a covariate in subsequent multivariable analyses (As shown in Table 2).

Table 2: Baseline Characteristics of Right Eyes Stratified by Fundus Subtypes.

Variable	Level	Normal / No identified abnormality	Exudative type	Isolated hemorrhagic type	Statistic	P.value
		N = 290	N = 47	N = 72		
birth weight(g)		**3.15 ± 0.53**	**3.17 ± 0.46**	**3.20 ± 0.57**	**1.042**	**0.59**
Gestational age (weeks)		**38.74 ± 1.88**	**39.12 ± 1.26**	**39.04 ± 1.44**	**1.161**	**0.56**
gender					**2.652**	**0.27**
	male	**145 (50%)**	**28 (59.6%)**	**42 (58.3%)**		
	female	**145 (50%)**	**19 (40.4%)**	**30 (41.7%)**		
Preterm birth					**1.580**	**0.45**
	Preterm birth	**48 (16.6%)**	**5 (10.6%)**	**9 (12.5%)**		
	Full-term birth	**242 (83.4%)**	**42 (89.4%)**	**63 (87.5%)**		

Variable	Level	Normal / No identified abnormality	Exudative type	Isolated hemorrhagic type	Statistic	P.value
		N = 290	N = 47	N = 72		
Plurality					4.326	0.12
	Singleton	274 (94.5%)	44 (93.6%)	72 (100%)		
	Multiple birth	16 (5.5%)	3 (6.4%)			
Mode of Delivery					36.874	0.00
	Vaginal Delivery	179 (61.7%)	30 (63.8%)	71 (98.6%)		
	Cesarean section	111 (38.3%)	17 (36.2%)	1 (1.4%)		
Forceps-assisted delivery					2.043	0.36
	Forceps-assisted	4 (1.4%)	2 (4.3%)	1 (1.4%)		
	No forceps	286 (98.6%)	45 (95.7%)	71 (98.6%)		
Oxygen therapy					1.269	0.53
	Yes	18 (6.2%)	1 (2.1%)	4 (5.6%)		
	No	272 (93.8%)	46 (97.9%)	68 (94.4%)		
Apgar Score					1.083	0.58
	Normal	284 (97.9%)	47 (100%)	71 (98.6%)		
	Abnormal	6 (2.1%)		1 (1.4%)		
Maternal anemia					3.776	0.15
	Yes	277 (95.5%)	46 (97.9%)	72 (100%)		
	No	13 (4.5%)	1 (2.1%)	NA		
Meconium-stained amniotic fluid					5.720	0.46
	No	279 (96.2%)	44 (93.6%)	68 (94.4%)		
	Grade I	2 (0.7%)	1 (2.1%)	1 (1.4%)		
	Grade II	1 (0.3%)	1 (2.1%)	2 (2.8%)		
	Grade III	8 (2.8%)	1 (2.1%)	1 (1.4%)		
Maternal syphilis during pregnancy					1.375	0.50
	Yes	7 (2.4%)		1 (1.4%)		
	No	283 (97.6%)	47 (100%)	71 (98.6%)		
Fetal distress					0.326	0.85
	Yes	8 (2.8%)	2 (4.3%)	2 (2.8%)		
	No	282 (97.2%)	45 (95.7%)	70 (97.2%)		
Premature rupture of membranes (PROM)					1.903	0.39
	Yes	19 (6.6%)	1 (2.1%)	6 (8.3%)		
	No	271 (93.4%)	46 (97.9%)	66 (91.7%)		
Group B Streptococcus (GBS)					0.180	0.91
	Yes	27 (9.3%)	5 (10.6%)	6 (8.3%)		
	No	263 (90.7%)	42 (89.4%)	66 (91.7%)		
Gestational hypertension					0.016	0.99
	Yes	13 (4.5%)	2 (4.3%)	3 (4.2%)		
	No	277 (95.5%)	45 (95.7%)	69 (95.8%)		
Gestational diabetes mellitus (GDM)					0.091	0.96
	Yes	56 (19.3%)	9 (19.1%)	15 (20.8%)		
	No	234 (80.7%)	38 (80.9%)	57 (79.2%)		
thyroid function					0.019	0.99
	Normal	271 (93.4%)	44 (93.6%)	67 (93.1%)		
	Abnormal	19 (6.6%)	3 (6.4%)	5 (6.9%)		

3.3 Visual and Refractive Outcomes by Neonatal Fundus Findings

No significant differences were observed among neonatal fundus categories with respect to age at fundus examination, interval between fundus examination and vision screening, and age at follow-up (all $P > 0.05$). No visual impairment was detected in any participant at follow-up (Shown in Table 3 and Table 4).

Table 3: Vision Screening Outcomes of Left Eyes Stratified by Fundus Subtypes

Variable	Level	Normal / No identified abnormality	Exudative type	Isolated hemorrhagic type	Statistic	P.value
		N = 291	N = 47	N = 71		
Timing characteristics						
Age at fundus examination (days)		3.58 ± 4.84	2.53 ± 1.16	2.69 ± 2.27	1.717	0.42
Interval between fundus exam and vision screening (days)		1316.54 ± 113.00	1321.00 ± 71.05	1336.25 ± 100.63	1.445	0.49
Age at vision examination (years)		3.61 ± 0.31	3.62 ± 0.19	3.67 ± 0.28	1.263	0.53
[Left-eye] Visual Acuity		4.85 ± 0.13	4.83 ± 0.11	4.85 ± 0.14	0.356	0.84
[Left-eye] Decimal Visual Acuity		0.73 ± 0.22	0.70 ± 0.17	0.75 ± 0.27	0.356	0.84
[Left-eye] LogMAR visual acuity		0.15 ± 0.13	0.17 ± 0.11	0.15 ± 0.14	0.356	0.84
[Left-eye] Sphere Power		1.08 ± 0.62	1.30 ± 1.03	1.13 ± 0.65	4.118	0.13
[Left-eye] Cylinder Power		-0.58 ± 0.44	-0.68 ± 0.41	-0.56 ± 0.43	3.341	0.19
[Left-eye] Axis		81.40 ± 64.53	101.37 ± 66.38	84.15 ± 66.94	3.856	0.15
[Left-eye] Spherical equivalent (SE)		0.79 ± 0.55	0.96 ± 1.02	0.86 ± 0.58	1.085	0.58
[Left-eye] Astigmatism		0.58 ± 0.44	0.68 ± 0.41	0.56 ± 0.43	3.341	0.19
[Left-eye] Clinically significant astigmatism					1.497	0.47
	Yes	86 (29.6%)	18 (38.3%)	21 (29.6%)		
	No	205 (70.4%)	29 (61.7%)	50 (70.4%)		
[Left-eye] Severity of astigmatism					3.196	0.78
	No	28 (9.6%)	3 (6.4%)	5 (7%)		
	Mild	177 (60.8%)	26 (55.3%)	45 (63.4%)		
	Moderate	82 (28.2%)	18 (38.3%)	20 (28.2%)		
	Severe	4 (1.4%)		1 (1.4%)		
[Left-eye] Type of astigmatism					2.106	0.91
	No	28 (9.6%)	4 (8.5%)	5 (7%)		
	With-the-rule astigmatism	160 (55%)	29 (61.7%)	44 (62%)		
	Against-the-rule astigmatism	59 (20.3%)	8 (17%)	11 (15.5%)		
	Oblique astigmatism	44 (15.1%)	6 (12.8%)	11 (15.5%)		
[Left-eye] Oblique astigmatism					0.199	0.91
	Yes	44 (15.1%)	6 (12.8%)	11 (15.5%)		
	No	247 (84.9%)	41 (87.2%)	60 (84.5%)		
[Left-eye] Visual impairment					NA	NA
	No visual impairment	291 (100%)	47 (100%)	71 (100%)		

Comparisons of visual and refractive parameters—including decimal visual acuity, LogMAR visual acuity, spherical power, cylindrical power, spherical equivalent, astigmatism magnitude, prevalence of clinically significant astigmatism, astigmatism severity, astigmatism type, and prevalence of oblique astigmatism—revealed no statistically significant differences among the three fundus categories (all $P > 0.05$). These findings were consistent in both left- and right-eye analyses (Shown in Table 3 and Table 4).

Table 4: Vision Screening Outcomes of Right Eyes Stratified by Fundus Subtypes.

Variable	Level	Normal / No identified abnormality	Exudative type	Isolated hemorrhagic type	Statistic	P.value
		N = 290	N = 47	N = 72		
Timing characteristics						
Age at fundus examination (days)		3.59 ± 4.85	2.77 ± 1.71	2.50 ± 1.96	3.104	0.21
Interval between fundus exam and vision screening (days)		1320.68 ± 111.51	1293.09 ± 88.07	1336.75 ± 97.00	3.298	0.19
Age at vision examination (years)		3.63 ± 0.31	3.55 ± 0.24	3.67 ± 0.27	3.219	0.20
[Right-eye] Visual Acuity		4.85 ± 0.12	4.85 ± 0.12	4.86 ± 0.17	0.296	0.86
[Right-eye] Decimal Visual Acuity		0.74 ± 0.20	0.74 ± 0.20	0.77 ± 0.29	0.296	0.86
[Right-eye] LogMAR visual acuity		0.15 ± 0.12	0.15 ± 0.12	0.14 ± 0.17	0.296	0.86
[Right-eye] Sphere Power		0.96 ± 0.54	1.16 ± 0.95	0.95 ± 0.55	3.465	0.18
[Right-eye] Cylinder Power		-0.56 ± 0.42	-0.58 ± 0.48	-0.57 ± 0.48	0.151	0.93
[Right-eye] Axis		81.23 ± 66.59	71.59 ± 63.22	67.70 ± 64.96	2.902	0.23
[Right-eye] Spherical equivalent (SE)		0.68 ± 0.49	0.88 ± 0.90	0.67 ± 0.50	2.404	0.30
[Right-eye] Astigmatism		0.56 ± 0.42	0.58 ± 0.48	0.57 ± 0.48	0.151	0.93
[Right-eye] Clinically significant astigmatism					1.190	0.55
	Yes	84 (29%)	10 (21.3%)	20 (27.8%)		
	No	206 (71%)	37 (78.7%)	52 (72.2%)		
[Right-eye] Severity of astigmatism					6.010	0.42
	No	36 (12.4%)	4 (8.5%)	11 (15.3%)		
	Mild	170 (58.6%)	33 (70.2%)	41 (56.9%)		
	Moderate	82 (28.3%)	10 (21.3%)	18 (25%)		
	Severe	2 (0.7%)		2 (2.8%)		
[Right-eye] Type of astigmatism					1.067	0.98
	No	36 (12.4%)	6 (12.8%)	11 (15.3%)		
	With-the-rule astigmatism	163 (56.2%)	26 (55.3%)	41 (56.9%)		
	Against-the-rule astigmatism	47 (16.2%)	9 (19.1%)	10 (13.9%)		
	Oblique astigmatism	44 (15.2%)	6 (12.8%)	10 (13.9%)		
[Right-eye] Oblique astigmatism					0.230	0.89
	Yes	44 (15.2%)	6 (12.8%)	10 (13.9%)		
	No	246 (84.8%)	41 (87.2%)	62 (86.1%)		
[Right-eye] Visual impairment					NA	NA
	No visual impairment	290 (100%)	47 (100%)	72 (100%)		

3.4 Baseline Characteristics by Severity of Retinal Hemorrhage

Subgroup analyses were conducted among infants with retinal hemorrhage according to hemorrhage severity. In the left-eye analysis, significant differences were observed in mode of delivery and meconium-stained amniotic fluid across

hemorrhage severity groups. Significant differences in mode of delivery were observed across hemorrhage severity groups ($P < 0.001$), with higher proportions of vaginal delivery in the hemorrhage groups, and the distribution of meconium-stained amniotic fluid differed significantly across hemorrhage severity groups in the left-eye analysis ($P = 0.04$) (Shown in Table 5).

Table 5: Baseline Characteristics of Left Eyes Stratified by Retinal Hemorrhage Severity.

Variable	Level	Normal / No identified abnormality	Mild Hemorrhage	Severe Hemorrhage	Statistic	P.value
		N = 276	N = 53	N = 18		
birth weight(g)		3.15 ± 0.54	3.21 ± 0.59	3.11 ± 0.42	1.255	0.53
Gestational age (weeks)		38.71 ± 1.87	39.20 ± 1.58	39.00 ± 1.37	4.073	0.13
gender					3.959	0.14
	male	136 (49.3%)	34 (64.2%)	9 (50%)		
	female	140 (50.7%)	19 (35.8%)	9 (50%)		
Preterm birth					0.511	0.77
	Preterm birth	44 (15.9%)	7 (13.2%)	2 (11.1%)		
	Full-term birth	232 (84.1%)	46 (86.8%)	16 (88.9%)		
SingletonMultiple birth					4.033	0.13
	Singleton	261 (94.6%)	53 (100%)	18 (100%)		
	Multiple birth	15 (5.4%)				
Mode of Delivery					35.747	0.00
	Vaginal Delivery	171 (62%)	52 (98.1%)	18 (100%)		
	Cesarean section	105 (38%)	1 (1.9%)	NA		
Forceps-assisted delivery					7.905	0.02
	Forceps-assisted	2 (0.7%)	3 (5.7%)	NA		
	No forceps	274 (99.3%)	50 (94.3%)	18 (100%)		
Oxygen therapy					0.746	0.69
	Yes	17 (6.2%)	3 (5.7%)	2 (11.1%)		
	No	259 (93.8%)	50 (94.3%)	16 (88.9%)		
Apgar Score					0.409	0.81
	Normal	270 (97.8%)	52 (98.1%)	18 (100%)		
	Abnormal	6 (2.2%)	1 (1.9%)			
Maternal anemia					3.198	0.20
	Yes	264 (95.7%)	53 (100%)	18 (100%)		
	No	12 (4.3%)				
Meconium-stained amniotic fluid					13.111	0.04
	No	267 (96.7%)	48 (90.6%)	17 (94.4%)		
	Grade I	1 (0.4%)	2 (3.8%)	NA		
	Grade II	1 (0.4%)	1 (1.9%)	1 (5.6%)		
	Grade III	7 (2.5%)	2 (3.8%)	NA		
Maternal syphilis during pregnancy					1.571	0.46
	Yes	6 (2.2%)				
	No	270 (97.8%)	53 (100%)	18 (100%)		
Fetal distress					2.114	0.35
	Yes	7 (2.5%)	3 (5.7%)			
	No	269 (97.5%)	50 (94.3%)	18 (100%)		
Premature rupture of membranes (PROM)					3.001	0.22
	Yes	18 (6.5%)	6 (11.3%)			
	No	258 (93.5%)	47 (88.7%)	18 (100%)		
Group B Strentococcus (GBS)					0.532	0.77
	Yes	26 (9.4%)	6 (11.3%)	1 (5.6%)		
	No	250 (90.6%)	47 (88.7%)	17 (94.4%)		
Gestational hypertension					1.088	0.58
	Yes	14 (5.1%)	2 (3.8%)			
	No	262 (94.9%)	51 (96.2%)	18 (100%)		
Gestational diabetes mellitus (GDM)					2.879	0.24
	Yes	53 (19.2%)	8 (15.1%)	6 (33.3%)		
	No	223 (80.8%)	45 (84.9%)	12 (66.7%)		
thyroid function					0.622	0.73
	Normal	257 (93.1%)	50 (94.3%)	16 (88.9%)		
	Abnormal	19 (6.9%)	3 (5.7%)	2 (11.1%)		

In the right-eye analysis, similarly elevated proportions of vaginal delivery were observed in both hemorrhage severity groups ($P < 0.001$), whereas no additional perinatal characteristics showed significant differences in the right-eye analysis (Shown in Table 6).

Table 6: Baseline Characteristics of Right Eyes Stratified by Retinal Hemorrhage Severity.

Variable	Level	Normal / No identified abnormality	Mild Hemorrhage	Severe Hemorrhage	Statistic	P.value
		N = 276	N = 51	N =20		
birth weight(g)		3.15 ± 0.54	3.22 ± 0.63	3.16 ± 0.40	1.204	0.55
Gestational age (weeks)		38.74 ± 1.89	38.97 ± 1.49	39.17 ± 1.33	0.978	0.61
gender					2.056	0.36
	male	137 (49.6%)	30 (58.8%)	12 (60%)		
	female	139 (50.4%)	21 (41.2%)	8 (40%)		
Preterm birth					0.620	0.73
	Preterm birth	44 (15.9%)	7 (13.7%)	2 (10%)		
	Full-term birth	232 (84.1%)	44 (86.3%)	18 (90%)		
SingletonMultiple birth					4.033	0.13
	Singleton	261 (94.6%)	51 (100%)	20 (100%)		
	Multiple birth	15 (5.4%)				
Mode of Delivery					35.894	0.00
	Vaginal Delivery	171 (62%)	51 (100%)	19 (95%)		
	Cesarean section	105 (38%)	NA	1 (5%)		
Forceps-assisted delivery					0.390	0.82
	Forceps-assisted	4 (1.4%)	1 (2%)	NA		
	No forceps	272 (98.6%)	50 (98%)	20 (100%)		
Oxygen therapy					0.969	0.62
	Yes	18 (6.5%)	2 (3.9%)	2 (10%)		
	No	258 (93.5%)	49 (96.1%)	18 (90%)		
Apgar Score					0.447	0.80
	Normal	270 (97.8%)	50 (98%)	20 (100%)		
	Abnormal	6 (2.2%)	1 (2%)			
Maternal anemia					3.198	0.20
	Yes	264 (95.7%)	51 (100%)	20 (100%)		
	No	12 (4.3%)				
Meconium-stained amniotic fluid					7.128	0.31
	No	265 (96%)	48 (94.1%)	19 (95%)		
	Grade I	2 (0.7%)	1 (2%)	NA		
	Grade II	1 (0.4%)	1 (2%)	1 (5%)		
	Grade III	8 (2.9%)	1 (2%)	NA		
Maternal syphilis during pregnancy					0.379	0.83
	Yes	5 (1.8%)	1 (2%)	NA		
	No	271 (98.2%)	50 (98%)	20 (100%)		
Fetal distress					0.791	0.67
	Yes	8 (2.9%)	2 (3.9%)	NA		
	No	268 (97.1%)	49 (96.1%)	20 (100%)		
Premature rupture of membranes (PROM)					3.415	0.18
	Yes	18 (6.5%)	6 (11.8%)	NA		
	No	258 (93.5%)	45 (88.2%)	20 (100%)		
Group B Streptococcus (GBS)					0.502	0.78
	Yes	27 (9.8%)	5 (9.8%)	1 (5%)		
	No	249 (90.2%)	46 (90.2%)	19 (95%)		
Gestational hypertension					1.160	0.56
	Yes	13 (4.7%)	3 (5.9%)	NA		
	No	263 (95.3%)	48 (94.1%)	20 (100%)		
Gestational diabetes mellitus (GDM)					0.458	0.80
	Yes	52 (18.8%)	10 (19.6%)	5 (25%)		
	No	224 (81.2%)	41 (80.4%)	15 (75%)		
thyroid function					0.381	0.83
	Normal	257 (93.1%)	48 (94.1%)	18 (90%)		
	Abnormal	19 (6.9%)	3 (5.9%)	2 (10%)		

3.5 Visual and Refractive Outcomes by Retinal Hemorrhage Severity

In both left- and right-eye analyses, no significant differences were observed among hemorrhage severity groups with respect to age at follow-up vision examination, visual acuity (decimal or LogMAR), refractive status (spherical power, cylindrical power, and spherical equivalent), or astigmatism-related parameters (astigmatism magnitude, severity, type, or prevalence of oblique astigmatism) (all $P > 0.05$). No participant was classified as having visual impairment at follow-up. These results were consistent between eyes (Table 7 and Table 8).

Table 7: Vision Screening Outcomes of Left Eyes Stratified by Retinal Hemorrhage Severity.

Variable	Level	Normal / No identified abnormality	Mild Hemorrhage	Severe Hemorrhage	Statistic	P.value
		N = 276	N = 53	N = 18		
Timing characteristics						
Age at fundus examination (days)		3.61 ± 4.93	2.62 ± 2.11	2.89 ± 2.76	1.786	0.41
Interval between fundus exam and vision screening (days)		1319.14 ± 111.62	1336.79 ± 111.93	1334.67 ± 58.06	0.899	0.41
Age at vision examination (years)		3.62 ± 0.31	3.67 ± 0.31	3.66 ± 0.16	0.793	0.46
[Left-eye] Visual Acuity		4.84 ± 0.13	4.85 ± 0.15	4.86 ± 0.10	0.507	0.78
[Left-eye] Decimal Visual Acuity		0.73 ± 0.22	0.75 ± 0.30	0.74 ± 0.17	0.507	0.78
[Left-eye] LogMAR visual acuity		0.16 ± 0.13	0.15 ± 0.15	0.14 ± 0.10	0.507	0.78
[Left-eye] Sphere Power		1.06 ± 0.60	1.18 ± 0.72	0.99 ± 0.33	0.471	0.79
[Left-eye] Cylinder Power		-0.57 ± 0.43	-0.59 ± 0.45	-0.44 ± 0.34	1.370	0.50
[Left-eye] Axis		82.21 ± 64.81	78.76 ± 64.20	99.71 ± 74.09	0.713	0.70
[Left-eye] Spherical equivalent (SE)		0.78 ± 0.54	0.89 ± 0.66	0.76 ± 0.27	1.032	0.60
[Left-eye] Astigmatism		0.57 ± 0.43	0.59 ± 0.45	0.44 ± 0.34	1.370	0.50
[Left-eye] Clinically significant astigmatism					2.062	0.36
	Yes	77 (27.9%)	18 (34%)	3 (16.7%)		
	No	199 (72.1%)	35 (66%)	15 (83.3%)		
[Left-eye] Severity of astigmatism					3.009	0.81
	No	27 (9.8%)	4 (7.5%)	1 (5.6%)		
	Mild	172 (62.3%)	31 (58.5%)	14 (77.8%)		
	Moderate	74 (26.8%)	17 (32.1%)	3 (16.7%)		

[Left-eye]Type of astigmatism	Severe	3 (1.1%)	1 (1.9%)		5.672	0.46
	No	27 (9.8%)	4 (7.5%)	1 (5.6%)		
	With-the-rule astigmatism	152 (55.1%)	30 (56.6%)	14 (77.8%)		
	Against-the-rule astigmatism	54 (19.6%)	11 (20.8%)			
	Oblique astigmatism	43 (15.6%)	8 (15.1%)	3 (16.7%)		
[Left-eye]Oblique astigmatism					0.026	0.99
	Yes	43 (15.6%)	8 (15.1%)	3 (16.7%)		
	No	233 (84.4%)	45 (84.9%)	15 (83.3%)		
[Left-eye] Visual impairment					NA	NA
	No visual impairment	276 (100%)	53 (100%)	18 (100%)		

Table 8: Vision Screening Outcomes of Right Eyes Stratified by Retinal Hemorrhage Severity.

Variable	Level	Normal / No identified abnormality	Mild Hemorrhage	Severe Hemorrhage	Statistic	P.value
		N = 276	N = 51	N =20		
Timing characteristics						
Age at fundus examination (days)		3.65 ± 4.96	2.47 ± 1.62	2.65 ± 2.72	2.907	0.23
Interval between fundus exam and vision screening (days)		1319.29 ± 112.41	1325.90 ± 103.11	1360.55 ± 77.19	2.984	0.22
Age at vision examination (years)		3.62 ± 0.31	3.64 ± 0.28	3.73 ± 0.21	2.833	0.24
[Right-eye] Visual Acuity		4.85 ± 0.12	4.86 ± 0.19	4.85 ± 0.12	0.320	0.85
[Right-eye] Decimal Visual Acuity		0.74 ± 0.21	0.78 ± 0.32	0.73 ± 0.20	0.320	0.85
[Right-eye] LogMAR visual acuity		0.15 ± 0.12	0.14 ± 0.19	0.15 ± 0.12	0.320	0.85
[Right-eye] Sphere Power		0.94 ± 0.52	0.98 ± 0.62	0.89 ± 0.36	0.441	0.80
[Right-eye] Cylinder Power		-0.55 ± 0.41	-0.52 ± 0.50	-0.66 ± 0.42	2.687	0.26
[Right-eye] Axis		81.66 ± 66.24	71.83 ± 66.21	53.33 ± 60.26	3.269	0.20
[Right-eye] Spherical equivalent (SE)		0.67 ± 0.45	0.71 ± 0.56	0.56 ± 0.29	2.053	0.36
[Right-eye] Astigmatism		0.55 ± 0.41	0.52 ± 0.50	0.66 ± 0.42	2.687	0.26
[Right-eye] Clinically significant astigmatism					0.641	0.73
	Yes	78 (28.3%)	13 (25.5%)	7 (35%)		
	No	198 (71.7%)	38 (74.5%)	13 (65%)		
[Right-eye] Severity of astigmatism					8.622	0.20
	No	35 (12.7%)	9 (17.6%)	2 (10%)		
	Mild	163 (59.1%)	29 (56.9%)	11 (55%)		
	Moderate	77 (27.9%)	11 (21.6%)	7 (35%)		
	Severe	1 (0.4%)	2 (3.9%)			
[Right-eye] Type of astigmatism					1.358	0.97
	No	35 (12.7%)	9 (17.6%)	2 (10%)		
	With-the-rule astigmatism	153 (55.4%)	28 (54.9%)	12 (60%)		
	Against-the-rule astigmatism	46 (16.7%)	7 (13.7%)	3 (15%)		
	Oblique astigmatism	42 (15.2%)	7 (13.7%)	3 (15%)		
[Right-eye] Oblique astigmatism					0.075	0.96
	Yes	42 (15.2%)	7 (13.7%)	3 (15%)		
	No	234 (84.8%)	44 (86.3%)	17 (85%)		
[Right-eye] Visual impairment					NA	NA
	No visual impairment	276 (100%)	51 (100%)	20 (100%)		

3.6 Multivariable Associations Between Retinal Hemorrhage and Visual Outcomes

In multivariable regression models constructed separately for each eye, and after adjustment for mode of delivery, refractive covariates (sphere power), age at follow-up vision examination, and timing of neonatal fundus examination, neither hemorrhage severity was independently associated with LogMAR visual acuity or cylindrical power (Table 9 and 10).

Table 9: Linear Regression Analysis of the Association Between Retinal Hemorrhage Severity and LogMAR Visual Acuity in Left Eyes

Term	Estimate	Std.Error	t.value	P.value	Estimate 95% CI	
					Lower	Upper
Retinal Hemorrhage Severity [Left-eye] Normal / No identified abnormality						
[Left-eye] Mild (Minor)	-0.001	0.002	-0.347	0.73	-0.005	0.003
[Left-eye] Severe (Extensive)	-0.001	0.003	-0.276	0.78	-0.007	0.005
[Left-eye] Spherical equivalent (SE)	0.004	0.001	3.465	0.00	0.002	0.007
Mode of DeliveryCesarean section	0.000	0.002	0.131	0.90	-0.003	0.003
Age at vision examination (years)	-0.002	0.002	-0.628	0.53	-0.006	0.003
Age at fundus examination (days)	0.000	0.000	1.716	0.09	0.000	0.001

Table 10: Linear Regression Analysis of the Association Between Retinal Hemorrhage Severity and LogMAR Visual Acuity in Right Eyes.

Term	Estimate	Std.Error	t.value	P.value	Estimate 95% CI	
					Lower	Upper
Retinal Hemorrhage Severity [Left-eye] Normal / No identified abnormality						
[Left-eye] Mild (Minor)	0.000	0.002	-0.217	0.83	-0.004	0.004
[Left-eye] Severe (Extensive)	0.002	0.003	0.568	0.57	-0.004	0.008
[Right-eye] Spherical equivalent (SE)	0.006	0.002	4.200	0.00	0.003	0.009
Mode of DeliveryCesarean section	0.000	0.002	0.158	0.87	-0.003	0.003
Age at vision examination (years)	-0.004	0.002	-1.598	0.11	-0.008	0.001
Age at fundus examination (days)	0.000	0.000	2.031	0.04	0.000	0.001

Estimated effect sizes were small, and all 95% confidence intervals for hemorrhage-related terms crossed the null value. Similarly, in logistic regression analyses, hemorrhage severity was not significantly associated with the risk of clinically significant astigmatism (Table 11 and 12) or oblique astigmatism (all P > 0.05) (Table 13 and 14). These findings were consistent across left- and right-eye analyses.

Table 11: Logistic Regression Analysis of the Association Between Retinal Hemorrhage Severity and Clinically Significant Astigmatism in Left Eyes.

Term	OR	Std.Error	z.value	P.value	OR 95% CI	
					Lower	Upper
Retinal Hemorrhage Severity [Left-eye] Normal / No identified abnormality						
[Left-eye] Mild (Minor)	1.105	0.376	0.266	0.79	0.519	2.278
[Left-eye] Severe (Extensive)	0.556	0.679	-0.864	0.39	0.120	1.874
[Left-eye] Sphere Power	5.429	0.286	5.926	0.00	3.198	9.807
Mode of DeliveryCesarean section	0.956	0.307	-0.148	0.88	0.519	1.737
Age at vision examination (years)	2.696	0.445	2.230	0.10	1.136	6.532
Age at fundus examination (days)	1.012	0.026	0.436	0.66	0.956	1.064

Table 12: Logistic Regression Analysis of the Association Between Retinal Hemorrhage Severity and Clinically Significant Astigmatism in Right Eyes.

Term	OR	Std.Error	z.value	P.value	OR 95% CI	
					Lower	Upper
Retinal Hemorrhage Severity [Left-eye] Normal / No identified abnormality						
[Left-eye] Mild (Minor)	0.705	0.436	-0.800	0.42	0.287	1.609
[Left-eye] Severe (Extensive)	1.447	0.554	0.667	0.50	0.465	4.182
[Right-eye] Sphere Power	17.719	0.422	6.816	0.00	8.143	42.787
Mode of DeliveryCesarean section	0.669	0.322	-1.251	0.21	0.351	1.245
Age at vision examination (years)	1.042	0.477	0.087	0.93	0.406	2.652
Age at fundus examination (days)	1.023	0.030	0.764	0.44	0.962	1.081

Table 13: Logistic Regression Analysis of the Association Between Retinal Hemorrhage Severity and Oblique Astigmatism in Left Eyes.

Term	OR	Std.Error	z.value	P.value	OR 95% CI	
					Lower	Upper
Retinal Hemorrhage Severity [Left-eye] Normal / No identified abnormality						
[Left-eye] Mild (Minor)	0.875	0.438	-0.306	0.76	0.350	1.985
[Left-eye] Severe (Extensive)	0.966	0.670	-0.052	0.96	0.212	3.202
[Left-eye] Sphere Power	1.251	0.251	0.894	0.37	0.731	2.008
[Left-eye] Astigmatism	0.590	0.417	-1.265	0.21	0.254	1.313
Mode of DeliveryCesarean section	0.827	0.350	-0.541	0.59	0.408	1.623
Age at vision examination (years)	0.729	0.507	-0.625	0.53	0.266	1.953
Age at fundus examination (days)	0.961	0.050	-0.812	0.42	0.852	1.037

Table 14: Logistic Regression Analysis of the Association Between Retinal Hemorrhage Severity and Oblique Astigmatism in Right Eyes.

Term	OR	Std.Error	z.value	P.value	OR 95% CI	
					Lower	Upper
Retinal Hemorrhage Severity [Left-eye] Normal / No identified abnormality						
[Left-eye] Mild (Minor)	0.788	0.458	-0.520	0.60	0.299	1.847
[Left-eye] Severe (Extensive)	0.857	0.662	-0.233	0.82	0.190	2.784
[Right-eye] Sphere Power	0.681	0.396	-0.969	0.33	0.293	1.363
[Right-eye] Astigmatism	1.090	0.423	0.204	0.84	0.470	2.483
Mode of DeliveryCesarean section	0.766	0.354	-0.752	0.45	0.373	1.511
Age at vision examination (years)	1.015	0.507	0.029	0.98	0.371	2.731
Age at fundus examination (days)	0.974	0.043	-0.625	0.53	0.876	1.042

4. Discussion

In this study, we systematically evaluated the association between neonatal retinal hemorrhage and subsequent visual and refractive development in childhood using a cohort

derived from routine neonatal fundus screening and refractive follow-up. Our results demonstrated that neonatal retinal hemorrhage—whether analyzed as a binary exposure or further stratified by hemorrhage severity—was not significantly associated with childhood visual acuity, astigmatism magnitude, clinically significant astigmatism, or the risk of oblique astigmatism. These findings were consistent across analyses of left and right eyes and remained robust after adjustment for potential perinatal and follow-up–related confounders.

Neonatal retinal hemorrhage is a relatively common fundus finding in the perinatal period, with its incidence and risk factors—particularly the strong association with vaginal or instrument-assisted delivery—well documented in previous studies [16] [17] [18]. However, most existing research has focused primarily on epidemiological characteristics, perinatal determinants, and short-term natural history, with limited evidence addressing potential long-term visual or refractive consequences.

Compared with prior reports, the present study extends current knowledge in two important aspects. First, we expanded outcome assessment beyond structural or short-term functional measures to include childhood refractive development, with particular emphasis on astigmatism and its axis orientation. Second, we incorporated severity-based stratification of retinal hemorrhage, allowing exploration of potential dose–response relationships. This approach complements previous imaging-based longitudinal studies that primarily focused on macular structural outcomes after resolution of neonatal retinal hemorrhage [7].

The lack of a significant association between neonatal retinal hemorrhage and later refractive outcomes observed in this study is biologically and developmentally plausible. Most neonatal retinal hemorrhages are confined to superficial retinal layers or peripheral regions and resolve spontaneously within weeks after birth, without causing persistent disruption to the macula or critical visual pathways. Even in cases with more extensive hemorrhage, such transient alterations may be insufficient to induce lasting impairment in visual development. Moreover, refractive development — particularly the evolution of astigmatism — is a dynamic, multifactorial process involving coordinated changes in corneal curvature, crystalline lens power, and axial elongation, guided by visual feedback mechanisms. Within this complex and long-term developmental framework, a short-lived retinal event occurring in the neonatal period may not be sufficient to override or substantially alter the overall trajectory of emmetropization. Given that oblique astigmatism has been consistently associated with a higher risk of amblyopia compared with astigmatism aligned closer to the principal meridians, we specifically examined whether neonatal retinal hemorrhage—particularly when severe—was associated with an increased risk of oblique astigmatism. However, even among children with extensive hemorrhage, no significant elevation in the risk of oblique astigmatism was observed.

This finding suggests that neonatal retinal hemorrhage, even when relatively severe, may not result in persistent or directionally biased degradation of visual input sufficient to influence astigmatic axis development. Clinically, this observation is reassuring and indicates that neonatal retinal hemorrhage alone may not serve as a reliable predictor of high-risk astigmatism patterns later in childhood. With the increasing implementation of neonatal fundus screening programs, the detection rate of retinal hemorrhage has risen substantially, often raising concerns among clinicians and parents regarding possible long-term visual consequences. The findings of this study suggest that, in the absence of other significant ocular or neurological conditions, isolated neonatal retinal hemorrhage does not appear to warrant additional refractive intervention or intensified follow-up solely on the basis of concern for future refractive abnormalities.

Importantly, this does not diminish the importance of routine pediatric vision and refractive screening. Rather, it supports a more evidence-based and proportionate approach to counseling and follow-up, emphasizing that neonatal retinal hemorrhage itself may not constitute an independent risk factor for adverse refractive development.

The strengths of this study include its basis in a real-world neonatal screening cohort, a relatively large sample size, and the systematic assessment of multiple clinically relevant refractive outcomes. Separate analyses of left and right eyes, combined with multivariable adjustment for key perinatal and follow-up variables, further enhance the robustness of the findings. Several limitations should also be acknowledged. First, the retrospective single-center design introduces the possibility of selection bias and residual confounding. Second, refractive follow-up was concentrated in early childhood, which may not fully capture longer-term refractive trajectories [20] [21] [22]. Third, classification of hemorrhage severity relied on clinical image interpretation; although consistent with routine practice, some degree of subjectivity cannot be entirely excluded.

5. Conclusions

In conclusion, this study demonstrates that neonatal retinal hemorrhage—whether considered in terms of presence or severity—was not associated with adverse visual or refractive outcomes in childhood in this cohort. These findings provide important evidence for the clinical interpretation of neonatal fundus screening results and support a conservative, evidence-based approach to follow-up in infants with isolated retinal hemorrhage.

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