Journal of Modern Rehabilitation

Research Article

Clinical Features of Surgery Candidates for Different Types of Extraocular Muscle Palsy

Masoud Khorrami-Nejad[1,2], **Mustafa Abdullah**[2*], **Babak Masoomian**[1]

1. Translational Ophthalmology Research Center, Farabi Eye Hospital, Tehran University of Medical Sciences, Tehran, Iran.
2. Department of Optometry, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.

Use your device to scan and read the article online

Citation Khorrami-Nejad M, Abdullah M, Masoomian B. Clinical Features of Surgery Candidates for Different Types of Extraocular Muscle Palsy. Journal of Modern Rehabilitation. 2024; 18(2):218-228. http://dx.doi.org/10.18502/jmr.v18i2.15979

doi http://dx.doi.org/10.18502/jmr.v18i2.15979

Article info:
Received: 23 Jun 2023
Accepted: 27 Feb 2023
Available Online: 01 Apr 2024

Keywords:
Extraocular muscles; Strabismus; Cranial nerve palsy; Third nerve palsy; Fourth nerve palsy; Sixth nerve palsy

ABSTRACT

Introduction: Clinical manifestations of cranial nerve palsies are of great importance, and surgeons should consider them before planning surgical protocol.

Materials and Methods: This retrospective study was conducted on preoperative hospital records of 598 Iranian patients with different types of extraocular muscle palsy, including third (90 patients), fourth (501 patients), and fifth (7 patients) nerve palsy at Farabi Hospital, Tehran Province, Iran.

Results: In terms of fourth nerve palsy, the mean spherical equivalent (SE) in the right and left eye was 0.23±1.51 and 0.19±1.45 diopter, respectively. Also, the mean angle of vertical deviation was 15.54±8.85 Δ at near and 15.66±8.93 Δ at far. In patients with third nerve palsy, the mean SE in the right and left eye was -0.02±2.08 and 0.08±1.95 diopter, respectively. Also, the mean angle of vertical deviation was 17.8±17.4 Δ at near and 17.8±17.5 Δ at far. In terms of six nerve palsy, the mean SE in the right and left eye was -1.27±3.37 and -1.08±2.52 diopter, respectively. Also, the mean angle of esotropia was 32.4±7.7 Δ at near and 33±6.7 Δ at far. The frequency of amblyopia in patients with third, fourth, and sixth nerve palsies was 21 patients (23.3%), 70(14%), and 4(57.1%), respectively.

Conclusion: The clinical characteristics of patients with different types of EOM palsy are remarkably different, which can be attributed to the different properties of these kinds of deviations.

*** Corresponding Author:**
Mustafa Abdullah
Address: *Department of Optometry, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran.*
E-mail: *mustafaabdullahhamza@gmail.com*

Introduction

Ocular movements in differet gazes are undertaken via six extraocular muscles (EOMs) located around the eyeball. Three cranial nerves, including the third nerve (oculomotor), fourth nerve (trochlear), and sixth nerve (abducens), innervate the EOMs. [1, 2]. The third cranial nerve innervates the superior rectus, inferior rectus, medial rectus, and inferior oblique muscles. The fourth and sixth cranial nerves innervate the superior oblique and lateral rectus muscles, respectively. Congenital or acquired damage to these cranial nerves can result in malfunction in the affected EOM [3].

Whenever the third cranial nerve is deactivated, four EOMs are involved; therefore, the eye cannot perform adduction, elevation, and depression. Ptosis and mydriasis are accompanied in these patients [4]. In those patients who suffer from third nerve paresis (partial third nerve palsy) or paralysis (complete third nerve palsy), incomitant deviation manifests during motility testing. The practitioners observe hypotropia in the upgaze and hypertropia in the downgaze in the affected eye due to the combined malfunction of the inferior rectus and superior rectus muscles. Third cranial nerve palsy in children is caused by congenital or acquired disorders. Surgical indications are prominent strabismus in the primary position, abnormal head posture, and diplopia [5, 6]. The main reason for acquired third nerve palsy in children and adults is closed-head trauma [7].

The superior oblique muscle is the sole EOM innervated by the fourth cranial nerve. Superior oblique muscle palsy is the most common type of vertical deviation secondary to the paralysis of EOM, resulting from malfunction of the fourth cranial nerve [8, 9]. The predominant clinical characteristics in patients who suffer from the fourth nerve palsy are vertical diplopia due to the ipsilateral hypertropia and compensatory head tilt to the opposite side (to compensate for the ipsilateral excyclotropia of the affected eye) [10, 11]. To differentiate the diagnosis of the fourth nerve palsy, the clinician should perform Parks-Bielschowsky's three-step test described elsewhere [12]. Superior oblique muscle palsy can be acquired or congenital, and in those patients who suffer from acquired fourth nerve palsy, the main reason is closed-head trauma. Superior oblique muscle palsy contributes to hypertropia on the affected side, resulting in head tilt. In cases with prominent vertical deviation, abnormal head posture, asthenopia, and diplopia, surgical intervention is indicated.

The lateral rectus muscle is the sole EOM innervated by the sixth cranial nerve. The main clinical presentation in patients suffering from the sixth nerve palsy is horizontal diplopia that worsens when the gaze is toward the affected eye and when the patient looks at distance fixation [13, 14]. The predominant clinical manifestation is incomitant esotropia. Like other acquired cranial nerve palsies, the sixth nerve palsy is mainly due to closed-head trauma. Other reasons for the sixth nerve palsy are neoplasms, infections, and inflammations in the subarachnoid space. As a result, whenever clinicians encounter patients with acute onset esotropia that is incomitant, they should refer the patients for magnetic resonance imaging (MRI) testing [15]. In patients with mild diplopia secondary to the small angle of esotropia, prism or unilateral occlusion may be indicated [16]. When the deviation is large and persists for more than six months, surgical intervention should be considered as an option [13].

The management strategies for different types of strabismus include the prescription of full refractive correction, unilateral occlusion of the sound eye, and surgical intervention [6]. In some patients with large-angle strabismus, surgery is the only viable method to restore ocular alignment. More than one surgical intervention may be indicated in rare cases with extremely large-angle strabismus. In subjects who had habitual refractive correction before surgery, it may be necessary to use them after surgery. In addition, orthoptic exercises in those patients with small residual angles can sometimes help decrease the magnitude of remaining strabismus. It is essential to conduct a surgical intervention in patients whose surgery is indicated at an early age. Practically, younger age at the time of surgery is a positive factor for achieving better results [1].

Previous studies investigated clinical, visual, and refractive patterns of patients who were affected by palsy of different cranial nerves, including the third, fourth, and sixth, cranial nerves [17, 18]. Deficiencies in EOMs due to isolated cranial nerve palsies can lead to annoying diplopia and remarkable abnormal head posture [19-21]. Clinicians need to be familiar with the clinical characteristics of patients with cranial nerve palsies. Clinical manifestations of cranial nerve palsies, including the angle of deviation at near and distance, visual acuity, refractive error, and the presence of amblyopia, are of great importance, and surgeons should consider them before planning surgical protocol. From the clinical perspective, these clinical features guide the formation of an appropriate differential diagnosis, rational clinical decision-making, and, ultimately, effective therapies

for this group of patients. This study was conducted to determine and compare various clinical presentations of patients who suffered from the third, fourth, and sixth cranial nerve palsies and were candidates for strabismus surgery. This study was first conducted to simultaneously evaluate the clinical characteristics of all nerves supplying EOMs.

Materials and Methods

This cross-sectional and retrospective study was conducted on preoperative hospital records of 598 Iranian patients with EOM palsy, including the third, fourth, and sixth nerve palsies candidates for surgical treatment. These records were derived from cases examined at Farabi Eye Hospital over 10 years, from January 1, 2012, to January 1, 2022. This study was approved as a retrospective study by the Ethics Committee of Tehran University of Medical Sciences before data collection to review patient records and data use (Code: IR.TUMS.FNM.REC.1401.141), and adheres to the tenets of the Declaration of Helsinki.

All medical documents of patients before surgery were checked, and if they met inclusion criteria, they were included in the study. The inclusion criteria included patients with confirmed congenital or acquired third, fourth, and sixth nerve palsies candidates for strabismus surgery. The exclusion criteria included patients with non-paralytic horizontal or vertical deviations, patients with known neurologic disorders, mental disabilities, plagiocephalic syndromes, craniofacial anomalies, and other skeletal and muscular abnormalities, and all patients who had a history of previous ocular surgery, such as strabismus and refractive surgery.

In the first step, routine ophthalmic examinations, such as manifest refraction, corrected distance visual acuity (CDVA) measurement, and fundus examination were performed. The refractive error was measured using autorefraction (Topcon KR-8900, Topcon Corporation, Tokyo, Japan), and the results were confirmed by the Heine beta 200 retinoscope (Heine Optotechnik, Herrsching, Germany). The CDVA was measured using a Snellen chart at 6 meters, and the results were converted to a logarithm of the minimum angle of resolution (logMAR) using this formula: logMAR=-log ($VA_{E\text{-}Snellen}$). The value of CDVA less than 20/400 was considered as follows: Finger count: 2.0 logMAR; hand motion: 2.3 logMAR; light perception: 2.6 logMAR; and no light perception (NLP)=2.9 logMAR. The deviation angle was measured by an alternate prism-cover test. Then, eye movements, and the presence of any overshoot and undershoot of the extraocular muscles were tested by motility test. Throughout the examinations, refractive correction was used by all participants. All measurements were made at a near fixation distance while fixing 20/30 optotypes on a near Snellen chart at a distance of 33 cm.

Unilateral amblyopia was defined based on the presence of ≥2 Snellen line differences in best CDVA and the CDVA less than 20/30 in the amblyopic eye with at least one of the following amblyogenic factors, anisometropia (difference in myopia, hyperopia, and astigmatism equal or more than 3.00 D, +1.00 D - and -1.50 D, respectively), strabismus, combined anisometropia and strabismus and a pathological result obscuring the visual axis. Bilateral amblyopia was defined as the bilateral reduction of CDVA (<20/40) with a high amount of spherical equivalent (SE) in both eyes (SE myopia, SE hyperopia, and astigmatism equal or more than -6.00 D, +4.00 D, and -2.50 D, respectively), or a pathological result obscuring the visual axis.

The Parks-Bielschowsky three-step test is used to isolate palsied muscle [22]. In the first step, the clinician looks for hyper- or hypo-deviation of the eye and then marks the affected muscles. The second step requires finding the affected muscles when the patient looks at the right or left gaze, in which the deviation angle increases. The third step requires the patient to tilt his/her head to the right and left side, and the examiner marks the affected muscles, which causes an increased deviation angle. Ultimately, after analyzing all three steps, the isolated palsied muscle was ascribed. For example, patients with the fourth nerve palsy of the right eye are characterized by right hypertropia and increasing deviation angle in the left gaze and right head tilt. Cases with the sixth nerve palsy manifest with ipsilateral esotropia and abduction deficit. Cases with the third nerve palsy are characterized by deficient adduction, elevation, and depression. Motility disorders are accompanied by ptosis and mydriasis in these patients.

Finally, the characteristics of visual and refractive parameters in the different types of congenital or acquired cranial nerve palsies were determined with EOMs and the mean CDVA, refractive error, including spherical component, cylindrical component, and SE, angle of deviation, and prevalence of amblyopia were compared between different types of cranial nerve palsies.

The collected data were analyzed using SPSS software, version 24 (IBM Inc., Chicago, USA), and descriptive and analytic statistical methods were reported in the form of tables and statistical indices. To describe quan-

titative data, statistical indices, such as Mean±standard deviation (SD), and qualitative representations of ratios and statistical tables were used. The normality tests were performed using the Shapiro–Wilk test. Independent sample t-test or Mann-Whitney test was applied to examine significant differences between patients with the different types of cranial nerve palsies, including the third, fourth, and sixth nerve palsies. The characteristics of visual and refractive parameters were determined in the different types of endotracheal tubes (ET). Statistical tests were performed at a level of 5% error.

Results

This study evaluated the medical records of 598 patients with different types of EOM palsy, including 501, 90, and 7 patients with third, fourth, and sixth nerve palsy, respectively.

Patients with fourth nerve palsy

The current study evaluated the medical records of 501 patients with fourth nerve palsy. The mean age of patients was 20.9±16.4 years (range, 1-81 years). One hundred and eighty-four patients (36.7%) were female, and 317 patients (63.3%) were male. Table 1 presents age, CDVA, refraction in both eyes (sphere, cylinder, and SE), and horizontal and vertical angle of deviation in patients with fourth nerve palsy. As shown in this table, of the 412 patients who participated in visual acuity measurement, the mean CDVA in the right and left strabismic eye was 0.05±0.13 and 0.07±0.16 logMAR, respectively. The mean SE in the right and left strabismic eye was 0.23±1.51 and 0.19±1.45 diopter, respectively. Also, the mean angle of vertical deviation was 15.54±8.85 Δ at near and 15.66±8.93 Δ at far. In patients with fourth nerve palsy, 70 patients (14%) were amblyopic, including 24 patients (4.8%), 16(3.2%), 3(0.6%), and 27(5.4%) with mild, moderate, severe, and bilateral amblyopia, respectively.

Table 1. Age, best-CDVA, refraction, and angle of deviation in patients with fourth nerve palsy

Variables			No.	Minimum	Maximum	Mean±SD
Age (y)			501	1.0	81.0	20.87±16.38
CDVA* (logMAR)		Right eye	412	0.00	1.00	0.05±0.13
		Left eye	412	0.00	1.05	0.07±0.16
		Difference	412	0.00	0.81	0.07±0.16
Refraction (diopter)	Right eye	Sphere	489	-8.25	15.00	0.50±1.44
		Cylinder	489	0.00	4.50	0.55±0.76
		Spherical equivalent	489	-9.13	15.00	0.23±1.51
	Left eye	Sphere	489	-5.50	8.50	0.49±1.37
		Cylinder	489	0.00	7.50	0.60±0.94
		Spherical equivalent	489	-6.88	7.63	0.19±1.45
Angle of deviation (primary position, PD)	Near	Horizontal	435	0	30	1.83±4.89
		Vertical	435	0	45	15.54±8.85
	Far	Horizontal	435	0	30	1.79±4.81
		Vertical	435	0	45	15.66±8.93

JMR

CDVA: Corrected distance visual acuity; PD: Prism diopter.

*CDVA <20/400 was considered as follows: Finger count=2.0 logarithm of the minimum angle of resolution (logMAR); Hand motion=2.3 logMAR; Light perception: 2.6 logMAR; NLP=2.9 logMAR.

Table 2. Age, best-CDVA, refraction, and angle of deviation in patients with third nerve palsy

Variables			No.	Minimum	Maximum	Mean±SD
Age (y)			90	1.0	69.0	31.0±17.8
CDVA* (logMAR)		Right eye	78	0.00	2.9	0.2±0.5
		Left eye	78	0.00	2.9	0.1±0.4
		Difference	78	0.00	0.9	0.1±0.2
Refraction (diopter)	Right eye	Sphere	81	-4.50	10.00	0.42±1.98
		Cylinder	81	0.00	5.50	0.87±1.21
		Spherical equivalent	81	-7.00	7.75	-0.02±2.08
	Left eye	Sphere	81	-6.00	8.00	0.49±1.87
		Cylinder	81	0.00	5.00	0.81±1.10
		Spherical equivalent	81	-7.25	7.00	0.08±1.95
Angle of deviation (primary position, PD)	Near	Horizontal	54	0	105	17.2±28.9
		Vertical	54	0	85	17.8±17.4
	Far	Horizontal	54	0	105	18.2±31.5
		Vertical	54	0	85	17.8±17.5

JMR

* CDVA <20/400 was considered as follows: Finger count= 2.0 logarithm of the minimum angle of resolution (logMAR); hand motion= 2.3 logMAR; light perception= 2.6 logMAR; No light perception (NLP)=2.9 logMAR.

CDVA: Corrected distance visual acuity; PD: Prism diopter.

Patients with third nerve palsy

The current study evaluated the patients' medical records of 90 patients with third nerve palsy. The mean age of patients was 31±17.8 years (range, 1-69 years). Twenty-seven patients (30%) were female, and 63(70%) were male. Table 2 presents age, CDVA, refraction in both eyes (sphere, cylinder, and SE), and horizontal and vertical angle of deviation in patients with third nerve palsy. As shown in this table, of the 78 patients who participated in visual acuity measurement, the mean CDVA in the right and left strabismic eye was 0.2±0.5 and 0.1±0.4 logMAR, respectively. The mean SE in the right and left strabismic eye was -0.02±2.08 and 0.08±1.95 diopter, respectively. Also, the mean angle of vertical deviation was 17.8±17.4 Δ at near and 17.8±17.5 Δ at far. In patients with third nerve palsy, 21 patients (23.3%) had amblyopia, including 2 patients (2.2%), 9(10%), 4(4.4%), and 6 with mild, moderate, severe, and bilateral amblyopia, respectively.

Patients with sixth nerve palsy

The current study evaluated the patients' medical records of 7 patients with sixth nerve palsy. The mean age of patients was 40±20.8 years (range, 20-72 years). Three patients (42.9%) were female, and 4(57.1%) were male. Table 3 presents age, CDVA, refraction in both eyes (sphere, cylinder, and SE), and horizontal and vertical angle of deviation in patients with sixth nerve palsy. As shown in this table, the mean CDVA in the right and left strabismic eye was 0.3±0.2 and 0.1±0.3 logMAR, respectively. The mean SE in the right and left strabismic eye was -1.27±3.37 and -1.08±2.52 diopter, respectively. Also, the mean angle of esotropia was 32.4±7.7 Δ at near and 33±6.7 Δ at far. Four patients (57.1%) had amblyopia, including three moderate unilateral and one bilateral amblyopic case.

Table 3. Age, best-CDVA, refraction, and angle of deviation in oatients with sixth nerve palsy

Variables			No.	Minimum	Maximum	Mean±SD
Age (y)			7	20.0	72.0	40.0±20.8
CDVA* (logMAR)		Right eye	7	0.00	0.52	0.3±0.2
		Left eye	7	0.00	0.70	0.1±0.3
		Difference	7	0.00	0.60	0.3±0.3
Refraction (diopter)	Right eye	Sphere	7	-6.00	1.00	-0.71±2.63
		Cylinder	7	0.00	4.00	1.13±1.55
		Spherical equivalent	7	-8.00	1.00	-1.27±3.37
	Left eye	Sphere	7	-3.00	1.00	-0.29±1.44
		Cylinder	7	0.00	6.00	1.58±2.33
		Spherical equivalent	7	-6.00	0.75	-1.08±2.52
Angle of deviation (primary position, PD)	Near	Horizontal	7	22	40	32.4±7.7
		Vertical	7	0	10	2.0±4.5
	Far	Horizontal	7	25	40	33.0±6.7
		Vertical	7	0	10	2.0±4.5

JMR

CDVA: Corrected distance visual acuity; PD: Prism diopter.

*CDVA <20/400 was considered as follows: Finger count: 2.0 logarithm of the minimum angle of resolution (logMAR); Hand motion= 2.3 logMAR; Light perception=2.6 logMAR; NLP=2.9 logMAR.

Comparing visual and refractive parameters among patients with different types of extraocular muscle (EOM) palsy

Table 4 presents the comparison of age and visual parameters among patients with different EOM nerve palsy. The mean age of patients with fourth nerve palsy was significantly lower than patients with third and sixth nerve palsy (P<0.001). As shown in this table, the mean CDVA in the right eyes of patients with fourth nerve palsy was significantly worse than in other cases (P<0.001). Table 5 presents the comparison of refractive parameters among patients with different EOM nerve palsy. The cylindrical refractive error in both eyes of patients with sixth nerve palsy was significantly higher than in other cases (both P<0.001).

Table 6 presents the comparison of the angle of deviation among patients with different EOM nerve palsy. Based on obtained results from this table, the mean angle of horizontal deviation at near and far in patients with sixth nerve palsy was significantly higher than in other cases (both P<0.001). On the other hand, the mean angle of vertical deviation at near and far in patients with third nerve palsy was significantly higher than in other groups (both P<0.001).

Discussion

From the clinical perspective, the clinical features of strabismic patients guide the formation of an appropriate differential diagnosis, rational clinical decision-making, and, ultimately, effective therapies for this group of patients. Optometrists and ophthalmologists should be aware of the characteristics of different types of strabismus in their clinics and at different age groups of patients to determine favorable management strategies and make attempts to warn parents about the consequences of childhood strabismus to decrease the rate of the afflicted population throughout the country. Accordingly, the costs being imposed on the health authorities will be significantly decreased.

Table 4. The comparison of age and visual parameters among patients with different extraocular muscle nerve palsy

Variables		No.	Mean±SD	Std. Error	95% Confidence Interval		Minimum	Maximum	P**
					Lower Bound	Upper Bound			
Age (y)	3rd nerve palsy	90	31.0±17.8	1.9	27.3	34.7	1	69	<0.001
	4th nerve palsy	501	20.9±16.4	0.7	19.4	22.3	1	81	
	6th nerve palsy	7	40.0±20.8	7.8	20.8	59.2	20	72	
	Total	598	22.6±17.1	0.7	21.2	24.0	1	81	
CDVA* (right eye, logMAR)	3rd nerve palsy	78	0.2±0.5	0.1	0.1	0.3	0	2.9	<0.001
	4th nerve palsy	411	0.1±0.1	0.0	0.0	0.1	0	1	
	6th nerve palsy	7	0.3±0.2	0.1	0.1	0.5	0	0.52	
	Total	496	0.1±0.2	0.0	0.1	0.1	0	2.9	
CDVA (left eye, logMAR)	3rd nerve palsy	76	0.1±0.4	0.0	0.0	0.2	0	2.9	0.076
	4th nerve palsy	412	0.1±0.2	0.0	0.1	0.1	0	1.05	
	6th nerve palsy	7	0.1±0.3	0.1	-0.1	0.4	0	0.7	
	Total	495	0.1±0.2	0.0	0.1	0.1	0	2.9	
Difference CDVA between eyes (logMAR)	3rd nerve palsy	71	0.1±0.2	0.0	0.1	0.2	0	0.9	<0.001
	4th nerve palsy	409	0.1±0.2	0.0	0.1	0.1	0	0.81	
	6th nerve palsy	7	0.3±0.3	0.1	0.0	0.5	0	0.6	
	Total	487	0.1±0.2	0.0	0.1	0.1	0	0.9	

JMR

CDVA: Corrected distance visual acuity; PD: Prism diopter.

*CDVA <20/400 was considered as follows: Finger count=2.0 logarithm of the minimum angle of resolution (logMAR); Hand motion=2.3 logMAR; Light perception: 2.6 logMAR; NLP=2.9 logMAR, **P<0.001 is considered as a significant level.

This study was conducted to evaluate the medical records of 598 patients with EOM palsy, including the third, fourth, and sixth nerve palsy. Previous studies investigated clinical, visual, and refractive patterns of patients suffering from palsy of different cranial nerves, including the third, fourth, and sixth, cranial nerves [17].

In a retrospective study, Mudgil and Repka reviewed the data of 41 patients with third cranial nerve palsy, including patients with oculomotor paresis and paralysis [5]. Participants in the study included children with onset of third nerve palsy less than 7.5 years old and included patients with different etiologies, including congenital (39%), traumatic (37%), and neoplastic (17%) oculomotor nerve palsy. Twenty out of 41 patients were followed for an average of 3.6 years. Twenty-nine (71%) out of 41 patients were diagnosed with visual reduction at the initial examination. Of the 20 patients who were followed for an average course of 3.6 years, only 6 patients (30%) had normal visual acuity at the time of initial evaluation. The rest of the patients (14 cases) had an average visual acuity of 20/133 at the initial evaluation. Seven of these 14 patients had amblyopia with an average visual acuity of 20/125. They proposed that this visual reduction may be due to cortical or optic nerve damage rather than amblyopia. In terms of refractive error, the authors reported that 5 of 20 children had significant SE refractive error differences (>1 D), with a range of 1 to 3 D, and all of these refractive error differences were due to more hyperopia in the paretic eye. Compared to their results, the medical records of 90 patients with third nerve palsy with a mean age of 31±17.8 years were evaluated. We

Table 5. The comparison of refractive parameters among patients with different extraocular muscle nerve palsy

Variables		No.	Mean±SD	Std. Error	95% Confidence Interval		Minimum	Maximum	P*
					Lower Bound	Upper Bound			
Sphere (right eye, diopter)	Third nerve palsy	81	0.42±1.98	0.22	-0.02	0.85	-4.50	10.00	0.150
	Fourth nerve palsy	489	0.50±1.44	0.07	0.37	0.63	-8.25	15.00	
	Sixth nerve palsy	6	-0.71±2.63	1.08	-3.47	2.06	-6.00	1.00	
	Total	576	0.48±1.54	0.06	0.35	0.60	-8.25	15.00	
Cylinder (right eye, diopter)	Third nerve palsy	81	0.87±1.21	0.13	0.61	1.14	0.00	5.50	0.002
	Fourth nerve palsy	489	0.55±0.76	0.03	0.49	0.62	0.00	4.50	
	Sixth nerve palsy	6	1.13±1.55	0.63	-0.50	2.75	0.00	4.00	
	Total	576	0.60±0.85	0.04	0.53	0.67	0.00	5.50	
SE (right eye, diopter)	Third nerve palsy	81	-0.02±2.08	0.23	-0.48	0.44	-7.00	7.75	0.042
	Fourth nerve palsy	489	0.23±1.51	0.07	0.09	0.36	-9.12	15.00	
	Sixth nerve palsy	6	-1.27±3.37	1.38	-4.81	2.27	-8.00	1.00	
	Total	576	0.18±1.63	0.07	0.04	0.31	-9.12	15.00	
Sphere (left eye, diopter)	Third nerve palsy	81	0.49±1.87	0.21	0.08	0.90	-6.00	8.00	0.419
	Fourth nerve palsy	489	0.49±1.37	0.06	0.37	0.62	-5.50	8.50	
	Sixth nerve palsy	6	-0.29±1.44	0.59	-1.80	1.21	-3.00	1.00	
	Total	576	0.49±1.45	0.06	0.37	0.60	-6.00	8.50	
Cylinder (left eye, diopter)	Third nerve palsy	81	0.81±1.10	0.12	0.57	1.06	0.00	5.00	0.013
	Fourth nerve palsy	489	0.60±0.94	0.04	0.52	0.69	0.00	7.50	
	Sixth nerve palsy	6	1.58±2.33	0.95	-0.86	4.03	0.00	6.00	
	Total	576	0.64±0.99	0.04	0.56	0.72	0.00	7.50	
SE (left eye, diopter)	Third nerve palsy	81	0.08±1.95	0.22	-0.35	0.52	-7.25	7.00	0.116
	Fourth nerve palsy	489	0.19±1.45	0.07	0.06	0.32	-6.87	7.63	
	Sixth nerve palsy	6	-1.08±2.52	1.03	-3.73	1.56	-6.00	0.75	
	Total	576	0.16±1.54	0.06	0.04	0.29	-7.25	7.63	

SE: Spherical equivalent.

JMR

*P<0.001 is considered as a significant level.

recognized that the mean values of the spherical component, cylindrical component, and SE in the right and left eye were 0.42 vs 0.49, 0.87 vs 0.81, and -0.02 vs 0.08 diopter, respectively. Also, the mean angle of vertical deviation was 17.8±17.4 Δ at near and 17.8±17.5 Δ at far. We also found that 21 patients (23.3%) had amblyopia, including 2 patients (2.2%), 9(10%), 4(4.4%), and 6 with mild, moderate, severe, and bilateral amblyo-

Table 6. The comparison of the angle of deviation among patients with different extraocular muscle nerve palsy

Variables		No.	Mean±SD	Std. Error	95% Confidence Interval		Mini-mum	Maxi-mum	P*
					Lower Bound	Upper Bound			
Horizontal (near, prism diopter)	Third nerve palsy	54	17.2±28.9	3.9	9.3	25.1	0	105	<0.001
	Fourth nerve palsy	435	1.8±4.9	0.2	1.4	2.3	0	30	
	Sixth nerve palsy	5	32.4±7.7	3.4	22.9	41.9	22	40	
	Total	494	3.8±12.0	0.5	2.8	4.9	0	105	
Vertical (near, prism diopter)	Third nerve palsy	54	18.2±31.5	4.3	9.6	26.8	0	105	<0.001
	Fourth nerve palsy	435	1.8±4.8	0.2	1.3	2.3	0	30	
	Sixth nerve palsy	5	33.0±6.7	3.0	24.7	41.3	25	40	
	Total	494	3.9±12.7	0.6	2.8	5.0	0	105	
Horizontal (far, prism diopter)	Third nerve palsy	54	17.8±17.4	2.4	13.0	22.5	0	85	0.003
	Fourth nerve palsy	435	15.5±8.8	0.4	14.7	16.4	0	45	
	Sixth nerve palsy	5	2.0±4.5	2.0	-3.6	7.6	0	10	
	Total	494	15.6±10.2	0.5	14.7	16.6	0	85	
Vertical (far, prism diopter)	Third nerve palsy	54	17.8±17.5	2.4	13.0	22.6	0	85	0.004
	Fourth nerve palsy	435	15.7±8.9	0.4	14.8	16.5	0	45	
	Sixth nerve palsy	5	2.0±4.5	2.0	-3.6	7.6	0	10	
	Total	494	15.8±10.3	0.5	14.9	16.7	0	85	

*P<0.001 is considered as a significant level.

JMR

pia, respectively. Our results were inconsistent with the study conducted by Hamed, in which the author found high magnitudes of myopia or hyperopia combined with high values of astigmatism [23]. This difference can be attributed to the study participants of Hamed's study, who had mostly congenital third nerve palsy, and lid involvement is highly possible. The higher prevalence of hyperopia in the study conducted by Mudgil and Repka [5] and our study can be explained by ciliary muscle involvement, which is innervated with the third cranial nerve and resultant accommodative dysfunction in these patients. Therefore, the emmetropization process can be disturbed.

Also, in a retrospective study, Bagheri et al. determined the preoperative clinical features of patients with congenital and acquired fourth nerve palsy (superior oblique muscle palsy) [10]. They reviewed the hospital records of 73 patients over 10 years. The percentages of different clinical characteristics in these patients were amblyopia (19.2%), head tilt (13.7%), chin down position (4.1%), facial asymmetry (6.8%), and tendon laxity (2.7%). Mean preoperative vertical deviation, exotropia, and esotropia were 16.1 Δ, 15 Δ, and 13.9 Δ, respectively. They also reported that 52 cases (71.2%) were myopic (Mean±SD= -0.5±0.3 D), and 20 cases (27.4%) were hyperopic (Mean±SD +2.3±1.4 D), and mean astigmatism was -0.3±0.1 D. In terms of angle of deviation, the mean vertical deviation was 16.2±8.3 Δ (range, 0-40) and horizontal deviation was in 48 cases (65.8%), including exotropia in 37 patients (50.7%) with a mean angle of deviation of 15±9.5 prism diopter (PD), and esotropia in 11(15.1%) with a mean angle of deviation of 13.9±11.5 PD. Comparing their results, the medical records of 501 patients with fourth nerve palsy with a mean age of 20.9±16.4 years were evaluated. We figured out that the mean SE in the right and left eye was 0.23±1.51 and 0.19±1.45 diopter, respectively. Also, the mean

angle of vertical deviation was 15.54±8.85 Δ at near and 15.66±8.93 Δ at far. In addition, 70 patients (14%) had amblyopia, including 24 patients (4.8%), 16(3.2%), 3(0.6%), and 27(5.4%) with mild, moderate, severe, and bilateral amblyopia, respectively.

In terms of sixth nerve palsy, the medical records of 7 patients with a mean age of 40±20.8 years were evaluated. We found that the mean CDVA in the right and left eyes was 0.3±0.2 and 0.1±0.3 logMAR. The mean SE in the right and left eye was -1.27±3.37 and -1.08±2.52 diopter, respectively. Also, the mean angle of esotropia was 32.4±7.7 Δ at near and 33±6.7 Δ at far. Furthermore, 4 patients (57.1%) had amblyopia, including 3 moderate unilateral and 1 bilateral amblyopic case. In terms of visual acuity and refractive error characteristics of patients with sixth nerve palsy and associated esotropia, the literature review showed no report of preoperative clinical data for these patients.

By comparing the clinical features of patients with different cranial nerve palsies, we found that the mean age of patients with fourth nerve palsy was significantly lower than patients with third and sixth nerve palsy (P<0.001). Also, the mean CDVA in the right eyes of patients with fourth nerve palsy was significantly worse than in other cases (P<0.001). Additionally, the cylindrical refractive error in both eyes of patients with sixth nerve palsy was significantly higher than in other cases (both P<0.001). The mean angle of horizontal deviation at near and far in patients with sixth nerve palsy was significantly higher than in other cases (both P<0.001). On the other hand, the mean angle of vertical deviation at near and far in patients with third nerve palsy was significantly higher than in other groups (both P<0.001).

Conclusion

The present study demonstrated different clinical characteristics of patients with different types of EOM palsy. As demonstrated, the clinical characteristics (CDVA, sphere, SE, cylinder, and angle of deviation) of these patients are remarkably different, which can be attributed to the different properties of these kinds of deviations. It is recommended that optometrists who examine visual disorders of strabismic patients pay more attention to the differences in clinical characteristics of patients with different types of EOM palsy. More ideal examinations in routine examinations lead to more precise diagnosis and detection of strabismus at a younger age.

The strength of the present study was its large sample size. Other strengths included a high response rate, the first retrospective on different forms of patients with different types of EOM palsy with the standardized sampling strategy, and visual testing methods. In terms of limitation, the study was retrospectively conducted in only one center and several examiners evaluated the patients. In addition, we selected only patients with different types of EOM palsy, and patients with functional strabismus were excluded. Another limitation was that we did not record postoperative data of patients who underwent surgical intervention to find the favorable and unfavorable predictors of surgery success in patients with different types of EOM palsy. Therefore, it is recommended that other researchers conduct a similar study to find visual and refractive patterns in different types of strabismus as well as postoperative evaluation.

Ethical Considerations

Compliance with ethical guidelines

All information on patients will be kept confidential. This study was approved as a retrospective study by the Ethics Committee of Tehran University of Medical Sciences before data collection to review patient records and use the data (Code: IR.TUMS.FNM.REC.1401.141), and adheres to the tenets of the Declaration of Helsinki.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Authors' contributions

Study design, DATA acquisition, data interpretation, drafting, and editing the manuscript: All authors; Analysis: Mustafa Abdullah and Masoud Khorrami-Nejad.

Conflict of interest

The authors declared no conflict of interest.

Acknowledgments

The authors thank all staff in the strabismus clinic of Farabi Eye Hospital, especially Prof. Mohammad Reza Akbari.

References

[1] Rush JA, Younge BR. Paralysis of cranial nerves III, IV, and VI. Cause and prognosis in 1,000 cases. Archives of Ophthalmology. 1981; 99(1):76-9. [DOI:10.1001/archopht.1981.03930010078006] [PMID]

[2] Lyons CJ, Godoy F, ALQahtani E. Cranial nerve palsies in childhood. Eye. 2015; 29(2):246-51. [DOI:10.1038/eye.2014.292] [PMID] [PMCID]

[3] Brazis PW. Isolated palsies of cranial nerves III, IV, and VI. Seminars in Neurology. 2009; 29(1):14-28. [DOI:10.1055/s-0028-1124019] [PMID]

[4] Modi P, Arsiwalla T. Cranial nerve III palsy. Treasure Island: StatPearls Publishing; 2022. [PMID]

[5] Mudgil AV, Repka MX. Ophthalmologic outcome after third cranial nerve palsy or paresis in childhood. Journal of AAPOS. 1999; 3(1):2-8. [DOI:10.1016/S1091-8531(99)70087-X] [PMID]

[6] Sadagopan KA, Wasserman BN. Managing the patient with oculomotor nerve palsy. Current Opinion in Ophthalmology. 2013; 24(5):438-47. [DOI:10.1097/ICU.0b013e3283645a9b] [PMID]

[7] Elston JS. Traumatic third nerve palsy. The British Journal of Ophthalmology. 1984; 68(8):538-43. [DOI:10.1136/bjo.68.8.538] [PMID] [PMCID]

[8] Keane JR. Fourth nerve palsy: Historical review and study of 215 inpatients. Neurology. 1993; 43(12):2439-43. [DOI:10.1212/WNL.43.12.2439] [PMID]

[9] Holmes JM, Mutyala S, Maus TL, Grill R, Hodge DO, Gray DT. Pediatric third, fourth, and sixth nerve palsies: A population-based study. American Journal of Ophthalmology. 1999; 127(4):388-92. [DOI:10.1016/S0002-9394(98)00424-3] [PMID]

[10] Bagheri A, Fallahi MR, Abrishami M, Salour H, Aletaha M. Clinical features and outcomes of treatment for fourth nerve palsy. Journal of Ophthalmic & Vision Research. 2010; 5(1):27-31. [PMID] [PMCID]

[11] Dosunmu EO, Hatt SR, Leske DA, Hodge DO, Holmes JM. Incidence and etiology of presumed fourth cranial nerve palsy: A population-based study. American Journal of Ophthalmology. 2018; 185:110-4. [DOI:10.1016/j.ajo.2017.10.019] [PMID] [PMCID]

[12] Manchandia AM, Demer JL. Sensitivity of the three-step test in diagnosis of superior oblique palsy. Journal of AAPOS. 2014; 18(6):567-71. [DOI:10.1016/j.jaapos.2014.08.007] [PMID] [PMCID]

[13] Lee MS, Galetta SL, Volpe NJ, Liu GT. Sixth nerve palsies in children. Pediatric Neurology. 1999; 20(1):49-52. [DOI:10.1016/S0887-8994(98)00090-3] [PMID]

[14] Moster ML, Savino PJ, Sergott RC, Bosley TM, Schatz NJ. Isolated sixth-nerve palsies in younger adults. Archives of Ophthalmology. 1984; 102(9):1328-30. [DOI:10.1001/archopht.1984.01040031078029] [PMID]

[15] Goodwin D. Differential diagnosis and management of acquired sixth cranial nerve palsy. Optometry. 2006; 77(11):534-9. [DOI:10.1016/j.optm.2006.08.014] [PMID]

[16] Merino P, Gómez de Liaño P, Villalobo JM, Franco G, Gómez de Liaño R. Etiology and treatment of pediatric sixth nerve palsy. Journal of AAPOS. 2010; 14(6):502-5. [DOI:10.1016/j.jaapos.2010.09.009] [PMID]

[17] Park UC, Kim SJ, Hwang JM, Yu YS. Clinical features and natural history of acquired third, fourth, and sixth cranial nerve palsy. Eye. 2008; 22(5):691-6. [DOI:10.1038/sj.eye.6702720] [PMID]

[18] Akbari MR, Khorrami-Nejad M, Kangari H, Akbarzadeh Baghban A, Ranjbar Pazouki M. Facial asymmetry in unilateral congenital superior oblique muscle palsy. Optometry and Vision Science. 2021; 98(11):1248-54. [DOI:10.1097/OPX.0000000000001793] [PMID]

[19] Kushner BJ. Ocular causes of abnormal head postures. Ophthalmology. 1979; 86(12):2115-25. [DOI:10.1016/S0161-6420(79)35301-5] [PMID]

[20] Khorrami-Nejad M, Akbari MR, Kangari H, Akbarzadeh Baghban A, Masoomian B, Ranjbar-Pazooki M. Abnormal head posture in unilateral superior oblique palsy. Journal of Binocular Vision and Ocular Motility. 2021 71(1):16-23. [DOI:10.1080/2576117X.2020.1845561] [PMID]

[21] Akbari MR, Khorrami-Nejad M, Kangari H, Akbarzadeh Baghban A, Ranjbar Pazouki M. Ocular abnormal head posture: A literature review. Journal of Current Ophthalmology. 2022; 33(4):379-87. [DOI:10.4103/joco.joco_114_20] [PMID] [PMCID]

[22] Lee JE, Yang HK, Kim JH, Hwang JM. Diagnostic utility of the three-step test according to the presence of the trochlear nerve in superior oblique palsy. Journal of Clinical Neurology. 2018; 14(1):66-72. [DOI:10.3988/jcn.2015.11.1.66] [PMID] [PMCID]

[23] Hamed LM. Associated neurologic and ophthalmologic findings in congenital oculomotor nerve palsy. Ophthalmology. 1991; 98(5):708-14. [DOI:10.1016/S0161-6420(91)32230-9] [PMID]