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ORIGINAL RESEARCH

Outcomes and Factors Associated with Successful Strabismus Surgery for Abducens Nerve Palsies: A Retrospective Study and Literature Review

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Purpose: Several studies reported surgical outcomes for abducens nerve palsy, but information on factors that affect treatment success remains lacking. These factors are crucial for developing a treatment plan and providing disease counseling. This study aimed to investigate the outcomes of strabismus surgery for abducens nerve palsy and determine the factors that influence its success, including a review of relevant literature.

Methods: This retrospective analysis included abducens nerve palsy cases, focusing on surgical interventions and relevant patient data, at the outpatient clinics of Phramongkutklao Hospital from April 1, 2012, to April 30, 2022. A relevant literature review included the surgical success rate and factors that influence surgical outcomes.

Results: This study enrolled 32 patients, including 19 with partial and 13 with complete abducens nerve palsy. The overall success rate of strabismus surgery was 78.1%. Trauma was the leading cause of abducens nerve palsy in this population (28.13%). Fisher's exact and Mann–Whitney *U*-tests revealed that shorter abducens nerve palsy onset and smaller preoperative angle were significantly associated with successful surgical outcomes of strabismus surgery among the groups. In contrast, subgroup analysis revealed that only preoperative smaller angles were significantly associated with good surgical outcomes in horizontal strabismus surgery. However, the vertical rectus muscle transposition group demonstrated no significant factors. The literature review revealed that the success rate of surgery in abducens nerve palsy was 25%–82.6% for horizontal rectus muscle surgery and 46.2%–91% for rectus muscle transposition.

Conclusion: The surgical success rate for abducens nerve palsy reached 78.1%, including 78.95% for partial and 76.92% for complete abducens nerve palsy. Notably, a shorter onset preceding surgery and a smaller preoperative angle significantly correlated with successful surgical outcomes one year postoperatively.

Plain Language Summary: Numerous studies have been conducted to determine the effectiveness of eye muscle surgery for abducens nerve palsy. However, there is still a lack of information on the various factors that can influence the success rate of the treatment. Understanding these factors is crucial for developing appropriate treatment plans and guidance for individuals with this condition. Our study aimed to examine the effectiveness of strabismus surgery for abducens nerve palsy and identify the factors that affect its success. This was achieved by reviewing relevant literature and analyzing cases from Phramongkutklao Hospital between April 1, 2012, and April 30, 2022. We included 32 patients with partial or complete abducens nerve palsy, with trauma being the leading cause of the condition in our group. The results showed that the surgery was successful in 78.1% of cases. Our analysis revealed that getting surgery sooner after the palsy started and having a smaller misalignment angle before surgery were associated with better outcomes. However, these factors only mattered for horizontal eye muscle surgery, not vertical muscle transposition. Previous studies have reported success rates for this condition ranging from 25% to 91%. Our study concludes that earlier surgery and certain preoperative factors can improve outcomes for individuals with abducens nerve palsy after eye muscle surgery.

Keywords: cranial nerve, sixth nerve, prognosis, surgery, strabismus

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Introduction

The abducens nerve exclusively innervates the lateral rectus muscle. Abducens nerve impairment causes incomitant esotropia, which worsens its effect on ocular movement. Consistently, studies revealed that abducens nerve palsy is the most prevalent among cranial nerve palsies, surpassing oculomotor and trochlear nerve impairments.[1–5] A recent study conducted in Korea revealed an estimated overall incidence rate of CN6 palsy of 4.66 per 100,000 person-years, with a 95% confidence interval (CI) of 4.26–5.08, within the general population.[6] This incidence demonstrates an age-related pattern, escalating notably after 60 years of age and reaching its peak within 70–74 years of age, possibly associated with the age-dependent increase of vasculopathy diseases.[6] Various factors, such as inflammation, infection, vasculopathy, and compressive lesions, were determined as potential etiological contributors to abducens nerve palsy.[1,2,5–7]

Affected patients in acquired conditions suffer from binocular diplopia. Unresolved problems subsequently affect daily activities. Various modalities have alleviated double vision, including patching, prism glasses, botulinum toxin injection, and surgical treatment.[8]

The recovery rate of abducens nerve palsy is approximately 44.1%–80%, and its overall recovery rate is reasonable compared with other ocular motor nerve palsy.[2,5,9] Strabismus surgery recovers binocular diplopia in partial or nonrecovery cases.[10,11] Surgical treatment depends on residual lateral rectus muscle function and ocular deviation degree. The surgical technique for maintaining lateral rectus function includes medial rectus recession with or without lateral rectus resection. Vertical rectus muscle transposition, either partial or full transposition, is the procedure of choice in the absence of lateral rectus muscle function or a more significant deviation. The success rate of surgical treatment is 25%–91%.[12–25] Several studies have reported promising results, but more evidence is required to determine reliable prognostic factors that predict favorable surgical outcomes in these cases. These factors are crucial when developing treatment plans and conducting preoperative counseling.

Therefore, this study aimed to report the types of surgical procedures, long-term success rates, and factors that influenced successful outcomes of abducens nerve palsy in a tertiary hospital, considering relevant literature reviews.

Materials and Methods

Study Participants

This retrospective chart review of electronic records from April 1, 2012, to April 30, 2022, was conducted at the outpatient department of Phramongkutklao Hospital. Strabismus procedures were determined using the International Classification of Diseases, Ninth Revision (ICD-9) codes 15.1–15.9, which was cross-referenced with the ICD-10 code H492 for abducens nerve palsy. Inclusion criteria were a diagnosis of unilateral abducens nerve palsy, experience of nonrecovery of symptoms for >6 months, and initial strabismus surgery, with data collected over a minimum 6-month follow-up period. The exclusion criteria were incomplete data or previous surgical interventions.

Ethics

The Institutional Review Board of the Royal Thai Army Medical Department (approval number S027h/66) reviewed and approved the study protocol. The study adhered to the tenets of the Declaration of Helsinki. Our Ethics committee waived written informed consent for publication because of the retrospective study design. Participant data were kept anonymous and confidential.

Disease Definition

Abducens nerve palsy is a neurological condition that is characterized by impaired abducens nerve function. This impairment limits abduction and frequently causes incomitant esotropia, where the inward deviation of the affected eye varies with gaze direction. Complete abducens nerve palsy indicates a severe condition with a complete loss of abduction and an affected eye that cannot move beyond the midline. In contrast, partial abducens nerve palsy denotes a milder manifestation where abduction is limited but can extend to some degree beyond the midline.

Surgical Intervention

Surgical interventions for abducens nerve palsy-related strabismus involve a range of procedures tailored to condition severity. Treatment options for partial abducens nerve palsy include unilateral medial rectus recession, monocular horizontal recession-resection, and bilateral medial rectus recession. Full tendon vertical rectus muscle transposition to the lateral rectus muscle, accompanied by Foster's suture surgery, is typically performed in complete abducens nerve palsy cases. The surgical dosage for recession and resection procedures follows the Marshall Park table, augmented by 1–2 mm from the standard surgical dose. Achieving ocular alignment within 10 prism diopters in the primary position indicates surgical success.

Data Gathered

General data were collected, including age, sex, onset duration, etiologies, duction limitation, stereopsis, preoperative angle, and surgical outcomes during the following period. The Randot stereotest was used to assess stereopsis, with any perception of the stereo test indicating the presence of stereopsis. A strabismus ophthalmologist evaluated duction limitation by measuring the duction range from the midline. Negative, zero, and positive percentages indicated that the duction did not pass the midline, was limited to the midline, and exceeded the midline position, respectively.

The PubMed search engine was used for English language articles with specific keywords, including "abducens nerve palsy", "sixth nerve palsy", "strabismus surgery", "muscle surgery", "superior rectus muscle transposition", and "vertical rectus muscle transposition", up to February 28, 2024. This search aimed to determine pertinent studies concerning both the success rates and prognostic determinants related to surgical interventions for abducens nerve palsy. Notably, the focus extended to determining prognostic markers that influence surgical outcomes in this particular patient cohort. The selection criteria included original articles and case series, whereas case reports were excluded.

Statistical Analysis

Descriptive statistics were used to analyze the essential characteristics of the sample group obtained from the general data. Quantitative data are presented in both absolute values and percentages. Mean and standard deviations were computed for normally distributed data, whereas median and interquartile ranges were used for nonnormally distributed data. The presentation of numbers and percentages helped summarize clustered data across different categories.

Fisher's exact test was used to evaluate standard distribution data, which is particularly useful for categorical variables and small sample sizes. Conversely, the Mann–Whitney *U*-test, which is adept at comparing ordinal or continuous variables without assuming specific population distributions, was used for unevenly distributed data. These statistical tests enabled data analysis, thoroughly considering its diverse distribution characteristics.

Results

Patient Demography

The data search included 138 cases, with 50 cases that underwent surgical treatment and 18 that were excluded from the study because of incomplete data.

The dataset comprised 32 surgical cases, including 13 complete abducens nerve palsy and 19 partial abducens nerve palsy. Table 1 shows demographic details. The mean age of the patients was 43.06 ± 16.45 years, with an average onset of palsy at 4.69 ± 5.82 years. Preoperatively, the mean angle measured 50.78 ± 24.23 prism diopters. Monocular horizontal muscle surgery and full tendon vertical rectus transposition were performed on 19 and 13 patients, respectively.

Table 1 Demographic Data in Abducens Nerve Palsy

	Success		Nonsuccess		*p*-value
	n	%	n	%	
Age					0.600
Mean ± SD	43.92 ± 17.68		40 ± 11.55		
Median (min–max)	42(4–74)		44(25–58)		
Onset (year)					0.017
Mean ± SD	2.88 ± 3		11.14 ± 8.76		
Median (min–max)	2(0.5–10)		10(1–20)		
Stereopsis					0.810
Present	6	85.7	1	14.3	
Absent	5	71.4	2	28.6	
Not record	14	77.8	4	22.2	
Etiology					0.771
Idiopathic	6	66.7	3	33.3	
vascular	6	85.7	1	14.3	
Carotid-cavernous fistula	2	100.0	0	0.0	
Increase in intracranial pressure	2	66.7	1	33.3	
Trauma	9	81.8	2	18.2	
Limitations of abduction (percentage pass midline)					0.563
mean ± SD	33.20 ± 43.5		25.71 ± 39.94		
Median (min–max)	40(−70.0–80)		10(–20–80)		
Number of surgical muscles					0.527
1	2	100.0	0	0.0	
2	21	75.0	7	25.0	
3	2	100.0	0	0.0	
Surgery					0.362
Unilateral recess	2	100.0	0	0.0	
Recess and resect	9	90.0	1	10.0	
Bilateral recess	4	57.1	3	42.9	
Vertical rectus transposition	10	76.9	3	23.1	
Preoperative angle (prism diopter)					0.005
Mean ± SD	44.6 ± 21.55		72.86 ± 21.19		
Median (min–max)	35(15–90)		80(40–90)		

Note: Data are presented as the mean ± SD, median (interquartile range), or n (%) of patients.
Abbreviations: SD, standard deviation; NA, not applicable.

Success Rate of Surgical Interventions

Comparative analysis revealed that shorter abducens nerve palsy onset (mean: 2.88 ± 3 years), preoperative angle, and postoperative angle at various time points, except for one year, were significantly associated with successful surgical outcomes of strabismus surgery among the groups ($p < 0.05$), as shown in Table 2.

Table 2 Postoperative Outcomes on Surgical Outcomes in Abducens Nerve Palsy

	Success		Nonsuccess		*p*-value
	n	%	n	%	
Postoperative (day 1)					0.001
Orthotropia	17	100.0	0	0.0	
Residual esotropia	6	46.2	7	53.8	
Consecutive exotropia	2	100.0	0	0.0	
Angle (day 1)					<0.001
Mean ± SD	2.12 ± 3.56		22.57 ± 19.66		
Postoperative (1 week)					0.006
Orthotropia	16	100.0	0	0.0	
Residual esotropia	8	53.3	7	46.7	
Consecutive exotropia	1	100.0	0	0.0	
Angle (1 week)					<0.001
Mean ± SD	2.36 ± 3.71		25.43 ± 15.94		
Postoperative (1 month)					0.001
Orthotropia	18	100.0	0	0.0	
Residual esotropia	7	50.0	7	50.0	
Angle (1 month)					<0.001
Mean ± SD	1.48 ± 2.54		26.14 ± 17.48		
Postoperative (3 months)					0.003
Orthotropia	16	100.0	0	0.0	
Residual esotropia	9	56.3	7	43.8	
Angle (3 months)					<0.001
Mean ± SD	1.44 ± 2.12		23.57 ± 16.99		
Postoperative (6 months)					0.008
Orthotropia	14	100.0	0	0.0	
Residual esotropia	11	61.1	7	38.9	
Angle (6 months)					<0.001
Mean ± SD	1.84 ± 2.23		24.43 ± 17.47		

(*Continued*)

Table 2 (Continued).

	Success		Nonsuccess		*p*-value
	n	%	n	%	
Postoperative (1 year)					0.061
Orthotropia	9	100.0	0	0.0	
Residual esotropia	16	69.6	7	30.4	
Angle (1 year)					<0.001
Mean ± SD	2.48 ± 2.26		19.71 ± 13.78		

Note: Data are presented as the mean ± SD or n (%) of patients.
Abbreviations: SD, standard deviation; NA, not applicable.

This study revealed a 78.1% overall success rate of surgical interventions. Specifically, the success rates for surgery in cases of partial and complete abducens nerve palsy were 78.95% (15 out of 19) and 76.92% (10 out of 13), respectively. Trauma appeared as the leading cause of abducens nerve palsy in the cohort, accounting for 28.13% (9 out of 32) of cases.

Tables 3 and 4 show the Fisher's exact and Mann–Whitney *U*-tests evaluating the success of horizontal strabismus surgery in patients with partial and complete abducens nerve palsy. Significant associations were observed between preoperative and postoperative angles and the successful outcome of horizontal muscle surgery in partial abducens nerve palsy. Moreover, the table shows the success of vertical rectus muscle transposition surgery in complete abducens nerve palsy cases. A significant association was revealed between the postoperative angle and the successful outcome of vertical rectus muscle transposition surgery in complete abducens nerve palsy.

Complication and Reoperation

This study revealed no complications in the strabismus surgeries. Two subjects who achieved an unsuccessful surgery underwent a second surgery. Both cases underwent horizontal muscle surgery in the first operation and another horizontal muscle resection for correction.

Discussion

This study revealed a 78.1% overall surgical success rate for abducens nerve palsy. Successful outcomes were more prominent in partial than complete nerve palsy.

Fisher's exact test revealed that a shorter onset preoperatively and a smaller angle preoperatively were significantly associated with a more successful abducens nerve palsy surgery, in the context of all abducens nerve palsy cases. The subgroup analysis revealed that the preoperative small angle was significantly associated with an excellent surgical outcome in the horizontal strabismus surgery group. However, the vertical rectus muscle transposition group demonstrated no significant factors.

This study revealed trauma as the predominant cause of abducens nerve palsy. However, noteworthy, no substantial disparity was observed between the condition's etiology and the subsequent success rates of strabismus surgical interventions.

Preoperative small strabismus angles indicate less severe ocular misalignment and potentially indicate a shorter misalignment duration in patients with abducens nerve palsy. These factors indicate better ocular motility and muscle function, making the extraocular muscles more amenable to surgical correction and potentially improving postoperative outcomes. Surgeons may find achieving optimal alignment and planning more precise surgical interventions easier when dealing with smaller preoperative angles.

The favorable outcomes associated with short-onset abducens nerve palsy during surgical interventions are associated with several key factors. First, the abrupt onset of abducens nerve palsy typically indicates preserved muscle function

Table 3 Subgroup Analysis of Factors Associated with Successful Surgical Treatment (Horizontal Strabismus vs Vertical Rectus Muscle Transposition Surgery)

Horizontal strabismus surgery						**Vertical rectus muscle transposition**					
	success		**Nonsuccess**		***p*–value**		**success**		**Nonsuccess**		***p*–value**
	n	**%**	**n**	**%**			**n**	**%**	**n**	**%**	
Age					0.515	**Age**					0.798
Mean ± SD		46.27 ± 22.04		38.75 ± 15.67		Mean ± SD	40.4±7.43		41.67 ± 4.93		
Onset (year)					0.116	**Onset (year)**					0.060
Mean ± SD		3.27 ± 3.6		9 ± 8.21		Mean ± SD	2.3±1.77		14 ± 10.39		
Stereopsis					0.827	**Stereopsis**					0.279
Present	3	75.0	1	25.0		Present	3	100.0	0	0.0	
Absent	12	80.0	3	20.0		Absent	7	70.0	3	30.0	
Etiology					0.708	**Etiology**					0.754
Idiopathic	4	66.7	2	33.3		Idiopathic	2	66.7	1	33.3	
Vascular	4	80.0	1	20.0		Vascular	2	100.0	0	0.0	
Carotid–cavernous fistula	1	100.0	0	0.0		Carotid–cavernous fistula	1	100.0	0	0.0	
Increase in intracranial pressure	2	66.7	1	33.3		Increase in intracranial pressure	0	0.0	0	0.0	
Trauma	4	100.0	0	0.0		Trauma	5	71.4	2	28.6	
Limitations of abduction (percentage pass midline)					0.794	**Limitations of abduction (percentage pass midline)**					0.728
Mean ± SD		54 ± 26.13		50 ± 35.59		Mean ± SD	2.00 ± 46.6		−6.67 ± 11.55		
Number of surgical muscles					0.622	**Number of surgical muscles**					0.569
1	2	100.0	0	0.0		1	0	0.0	0	0.0	
2	12	75.0	4	25.0		2	9	75.0	3	25.0	
3	1	100.0	0	0.0		3	1	100.0	0	0.0	

(*Continued*)

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Table 3 (Continued).

Horizontal strabismus surgery						Vertical rectus muscle transposition					
	success		Nonsuccess		*p*–value		success		Nonsuccess		*p*–value
	n	%	n	%			n	%	n	%	
Surgery					0.195	**Surgery**					NA
Unilateral recess	2	100.0	0	0.0		Unilateral recess	0	0.0	0	0.0	
Recess and resection	9	90.0	1	10.0		Recess and resection	0	0.0	0	0.0	
Bilateral recess	4	57.1	3	42.9		Bilateral recess	0	0.0	0	0.0	
Vertical rectus muscle transposition	0	0.0	0	0.0		Vertical rectus muscle transposition	10	76.9	3	23.1	
Preoperative angle					0.004	**Preoperative angle**					0.165
Mean ± SD		32 ± 9.6		65 ± 26.14		Mean ± SD	63.5 ± 20.82		83.33 ± 5.77		

Note: Data are presented as the mean ± SD or n (%) of patients.
Abbreviations: SD, standard deviation; NA, not applicable.

Table 4 Subgroup Analysis of Factors Associated with Successful Surgical Treatment (Horizontal Strabismus Vs Vertical Rectus Muscle Transposition Surgery) (Continue Table)

Horizontal strabismus surgery						**Vertical rectus muscle transposition**					
	Success		**Nonsuccess**		***p*-value**		**Success**		**Nonsuccess**		***p*-value**
	n	**%**	**n**	**%**			**n**	**%**	**n**	**%**	
Postoperative (day 1)					0.004	**Postoperative (day 1)**					0.188
ortho	12.0	100	0.0	0		ortho	5	100	0	0	
residual	2.0	33.3	4.0	66.7		residual	4	57.1	3	42.9	
consecutive	1.0	100	0.0	0		consecutive	1	100	0	0	
Angle (day 1)					0.002	Angle (day 1)					0.018
mean ± SD		1.53 ± 3.48		22.5 ± 25.8		mean ± SD	3 ± 3.68		22.67 ± 12.7		
Postoperative (1 week)					0.003	**Postoperative (1 week)**					0.296
ortho	12.0	100	0.0	0		ortho	4	100	0	0	
residual	3.0	42.9	4.0	57.1		residual	5	62.5	3	37.5	
consecutive	0.0	0	0.0	0		consecutive	1	100	0	0	
Angle (1 week)					0.001	**Angle (1 week)**					0.010
mean ± SD		1.13 ± 2.8		26.5 ± 19.12		mean ± SD	4.2 ± 4.26		24 ± 14.42		
Postoperative (1 month)					0.001	**Postoperative (1 month)**					0.118
ortho	13.0	100	0.0	0		ortho	5	100	0	0	
residual	2.0	33.3	4.0	66.7		residual	5	62.5	3	37.5	
Angle (1 month)					<0.001	**Angle (1 month)**					0.009
mean ± SD		0.67 ± 1.8		27.25 ± 21.99		mean ± SD	2.7 ± 3.06		24.67 ± 13.61		
Postoperative (3 months)					0.008	**Postoperative (3 months)**					0.118
ortho	11.0	100	0.0	0		ortho	5	100	0	0	
residual	4.0	50	4.0	50		residual	5	62.5	3	37.5	

(*Continued*)

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Table 4 (Continued).

Horizontal strabismus surgery						Vertical rectus muscle transposition					
	Success		**Nonsuccess**		***p*-value**		**Success**		**Nonsuccess**		***p*-value**
	n	**%**	**n**	**%**			**n**	**%**	**n**	**%**	
Angle (3 months)					0.001	**Angle (3 months)**					0.009
mean ± SD		0.93 ± 1.67		24.25 ± 20.56		mean ± SD	2.2 ± 2.57		22.67 ± 15.14		
Postoperative (6 months)						**Postoperative (6 months)**					
ortho	10.0	100	0.0	0		ortho	4	100	0	0	
residual	5.0	55.6	4.0	44.4		residual	6	66.7	3	33.3	
Angle (6 months)					0.001	**Angle (6 months)**					0.009
mean ± SD		1.2 ± 1.82		26 ± 22.8		mean ± SD	2.8 ± 2.53		22.33 ± 11.15		
Postoperative (1 year)					0.086	**Postoperative (1 year)**					0.400
ortho	7.0	100	0.0	0		ortho	2	100	0	0	
residual	8.0	66.7	4.0	33.3		residual	8	72.7	3	27.3	
Angle (1 year)					0.002	**Angle (1 year)**					0.010
mean ± SD		2 ± 2		24.5 ± 17.23		mean ± SD	3.2 ± 2.53		13.33 ± 4.16		

Note: Data are presented as patients' mean ± SD or n (%).
Abbreviations: SD, standard deviation; NA, not applicable.

because the extraocular muscles are less likely to have undergone substantial structural changes or contractures. Consequently, this preserved muscle integrity enables a more effective response to surgical correction. Second, the reduced abducens nerve palsy duration diminishes the risk of muscle fibrosis or contracture development, which could otherwise complicate surgical procedures by restricting the range of motion and diminishing surgical efficacy. Moreover, early identification and intervention in abducens nerve palsy cases facilitate prompt surgical treatment, thereby averting further ocular misalignment and fostering improved postoperative recovery. The abbreviated misalignment period mitigates the adaptive processes of the visual systems, which culminate in superior postsurgical outcomes. These Results emphasize the critical role of timely intervention and highlight the importance of recognizing the influence of onset duration on surgical success in managing abducens nerve palsy.

The number of cases of residual esotropia increased during the long-term follow-up, with the highest increase one year postoperatively in both partial and complete abducens nerve palsy cases. Specifically, residual esotropia steadily increased and peaked at one year in partial abducens nerve palsy cases. Similarly, the occurrence of residual esotropia demonstrated a significant increase among complete abducens nerve palsy cases, with the highest number recorded one year postoperatively. The residual esotropia and isotropic drift increase may be due to several factors. Firstly, the natural abducens nerve palsy progression causes muscle weakness or fibrosis over time, which affects postoperative eye alignment. Secondly, incomplete or suboptimal initial surgical correction causes residual misalignment as compensatory mechanisms weaken. Lastly, neural control changes of eye movements due to neuroplasticity may contribute as the brain adapts to altered input from the extraocular muscles. This increase indicates an isotropic drift in these groups, highlighting the importance of continuous monitoring and the potential for further intervention in managing residual esotropia in patients with abducens nerve palsy.

A literature review was performed in PubMed search engines using the keywords “abducens nerve palsy”, “sixth nerve palsy”, “strabismus surgery”, “muscle surgery”, “superior rectus muscle transposition”, and “vertical rectus muscle transposition” (Table 5). The success rate of participants who underwent horizontal rectus muscle surgery was 25%–82.6%,[12,13,24] and that of rectus muscle transposition was 46.2%–91%.[16,20,21] The success rate of the horizontal rectus muscle in the present study was higher than that reported in previous literature. In contrast, the success rate of vertical rectus muscle surgery was comparable to that of previous studies.

Limited research has investigated prognostic factors in strabismus surgery for abducens nerve palsy. Liu et al[19] reported 13 cases of abducens nerve palsy treated with augmented superior rectus transposition, with 6 cases achieving successful outcomes within 10 prism diopters in the primary position, accounting for a success rate of 46.2%. Their study revealed the degree of abduction deficit as a predictor of favorable surgical prognosis using multivariate analysis. However, these findings did not corroborate this association.

Alghofaili et al[23] revealed an overall surgical success rate of 67.3% (95% CI: 54.9–79.7) for abducens nerve palsy. Vertical rectus transposition and horizontal recession-resection were the most prominent surgical procedures, accounting for 34.5% and 32.7% of all cases, respectively. They revealed that bilateral abducens nerve palsy, higher preoperative angle, and a greater degree of abduction limitation were significantly associated with undercorrected strabismus outcomes, consistent with the present study’s observation that higher preoperative angles resulted in unsuccessful outcomes. However, the degree of abduction limitation did not significantly affect surgical outcomes in the present study in contrast to the findings of Alghofaili et al.

O’Brien et al[25] conducted a retrospective study on the success rate of strabismus surgery in abducens nerve palsy. They revealed a 53.6% success rate for a single operation, which increased to 73.7% for additional surgeries. The study revealed the preoperative abduction deficit as the only predictive factor for the surgical success rate. The milder deficit had the highest odds of initial (odds ratio [OR] = 5.555; 95% CI: 2.722–11.336) and final successes (OR = 5.294; 95% CI: 1.931–14.512). The research revealed that survival time before further surgery, abduction deficit severity, older age, other coincidental motility abnormalities, greater magnitude esotropia, and surgical technique predicted repeat surgical incidence. However, the current study revealed no significant effect of abduction deficit on successful surgical outcomes.

The present study revealed the association between the short onset of abducens nerve palsy and small preoperative angles, indicating their significant association with favorable surgical outcomes in abducens nerve palsy cases. These results reveal that both short-onset duration and smaller preoperative angles are valuable prognostic factors for achieving excellent surgical results in treating abducens nerve palsy.

Table 5 Results of Strabismus Surgery for Abducens Nerve Palsy

Study	Holm JM et al[12]	Holm JM et al[13]	Bansal S et al[14]	Leiba H et al[15]	Yurdakul NS et al[16]	Patil–Chhablani P et al[17]	Kozeis N et al[18]	Liu Y et al[19]	Hongler tnapakul W et al[20]	Noh H et al[21]	Farid MF et al[22]	Alghofaili R et al[23]	Wang Z et al[24]	O'Brien et al[25]	Our study
	2001	2002	2006	2010	2011	2016	2018	2018	2019	2019	2021	2021	2021	2023	
Population	27	31	21	22	17	13	20	13	20	11	10	55	36	209	32
Partial/complete abducens nerve palsy	NA	14/17	0/21	0/22	NA	NA	0/20	NA	0/20	NA	0/10	NA	0/36	NA	19/13
Follow–up (months)	6	24	6	44.2 ± 37.4	18.7±12	5.2 (1.5–12)	12	9.5(6–13)	24	42±20	6.4	24	8.4±6	NA	12
Criteria success	<10 PD, absent diplopia	<10 PD, absent diplopia	<10 PD, absent diplopia	<10 PD	<10 PD	<10 PD	<10 PD	<10 PD	<10 PD, absent diplopia	<10PD	<10PD	<10 PD	Orthotropia	<10 PD	<10 PD
% success type of surgery (N)															
Recess and resection	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	78.95(19)
Supramaximal recess and resect	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	82.6(30)	NA	NA
Vertical rectus muscle transposition	NA	NA	55.6(10)	NA	80(4)	NA	NA	NA	55(9)	91(10)	NA	NA	NA	NA	76.92(13)
Vertical rectus muscle transposition plus Botox	NA	NA	NA	59(13)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vertical rectus muscle transposition and medial rectus recess	NA	NA	NA	NA	83.3(5)	NA	88(17)	NA	NA	NA	NA	NA	NA	NA	NA
Vertical rectus muscle transposition with traction suture	NA	NA	NA	NA	80(4)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Augmented superior rectus transposition and medial rectus recess	NA	NA	NA	NA	NA	69(9)	NA	46.2(6)	NA	NA	60(6)	NA	NA	NA	NA
Muscle surgery (not define)	39(19)	52(12)	NA	NA	NA	NA	NA	NA	NA	NA	NA	67.3(55)	NA	53.6(116)	NA
Muscle surgery (not define) plus Botox	25(8)	50(4)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: Data are presented as n (%) of patients.
Abbreviations: NA, not applicable; D, diopter; N, population; PD, prism diopter.

Limitations

This study has several Limitations. First, its retrospective design may have introduced selection bias or caused incomplete data collection. Second, this is a single-center study; thus, the generalizability of these results to broader populations may be constrained, which potentially affects specific practices. Third, the study's limited follow-up period extends significantly beyond the timeframe, potentially affecting the comprehensiveness of the observations. Fourth, the retrospective data collection process may have affected data completeness. Fifth, the statistical usage only evaluated the significant difference between groups without a cause–result relationship. More participants were required for statistical analysis because of the limited sample size for calculation. Finally, the absence of a control group limits the ability to compare surgical outcomes with alternative treatment modalities, including nonsurgical interventions or different surgical techniques.

This manuscript will investigate various aspects to improve the understanding of successful strabismus surgery in abducens nerve palsy. This could involve conducting long-term follow-up studies to assess sustainability, prospective investigations to determine predictive factors, comparative analyses of surgical techniques, meta-analyses of existing literature, and evaluations of functional outcomes and quality-of-life measures. This research optimizes patient care and treatment strategies for this condition.

Conclusion

This study reported a 78.1% overall success rate of strabismus surgery for abducens nerve palsy. Interestingly, partial abducens nerve palsy demonstrated a marginally higher success rate of 78.95% compared with complete abducens nerve palsy, which achieved a success rate of 76.92%. Notably, a significant positive correlation was established between the shorter onset duration of abducens nerve palsy and favorable surgical outcomes. Moreover, these results revealed no significant disparities in success rates based on the etiology or type of surgery used for addressing abducens nerve palsy within the scope of this investigation.

Data Sharing Statement

This article include all data generated or analyzed during this study. Further inquiries should be directed to the corresponding authors.

Ethics Approval and Consent to Participate

The Institutional Review Board of the Royal Thai Army Medical Department reviewed and approved the study protocol (approval number S027h/66). Written informed consent for publication was waived because of the retrospective nature of the study. Participant data were kept anonymous and confidential.

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Author Contributions

An author made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; has agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interests in this work.

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