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Original Article

Association between external ophthalmoplegia with diplopia due to brain injury and FIM motor items: a case-control study

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ABSTRACT
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Objectives: This study aimed to determine the association between the presence of external ophthalmoplegia with diplopia due to brain injury and Functional Independence Measure (FIM) motor items in a case-control study.
Methods: The subjects were patients with brain injury, admitted to a convalescent rehabilitation ward, who were able to walk under supervision and had preserved intellectual function. The correlation between the strabismus angle of the external ophthalmoplegia group and the total points of FIM motor items were examined. In addition, the total points and sub-items were compared between the external ophthalmoplegia group and control group using statistical processing.
Results: There were 78 subjects: 34 in the external ophthalmoplegia group and 44 in the control group. Strabismus angle and the total points of FIM motor items of the external ophthalmoplegia group were significantly negatively correlated. Compared with the control group, the external ophthalmoplegia group had significantly lower levels of independence in bathing, dressing (lower body), toileting, transfer to the chair, transfer to the toilet, transfer to the bathroom, and locomotion (walking).
Conclusions: External ophthalmoplegia with diplopia is associated with FIM motor items.

Key words: external ophthalmoplegia, brain injury, FIM, convalescent rehabilitation ward

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Introduction

External ophthalmoplegia with diplopia causes severe discomfort and livelihood disability in patients. In a questionnaire survey of patients who presented with diplopia due to acquired external ophthalmoplegia, 85% answered that the condition limited their lives [1]. Using a questionnaire on daily life, Oka [2] also reported that external ophthalmoplegia caused severe disability in life at home, in activities such as ascending stairs, driving, and reading.

Fowler et al. [3] reported that 37% of patients with brain injury had some type of eye misalignment. In the Kaifukuki (convalescent) rehabilitation ward (convalescent ward), some patients with brain injury who had diplopia due to external ophthalmoplegia were also present. Although it can be inferred that external ophthalmoplegia affects life, no previous reports have described its effect on independence, in activities of daily living (ADL). When considering rehabilitative interventional policies for improving ADL capacity, it is important to examine the association between Functional Independence Measure (FLM) motor items, convalescent ward outcomes, and external ophthalmoplegia with diplopia.

This case-control study aimed to determine the association between external ophthalmoplegia with diplopia due to brain injury and FIM motor items in a convalescent rehabilitation ward.

Methods

1. Study design

The association between the presence of external

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ophthalmoplegia with diplopia and FIM motor items was investigated by a retrospective case-control study.

2. Subjects

Among patients admitted to the convalescent ward of Hospital A during an eight-year period from January 2011 to December 2019, those who met the following criteria were selected for the external ophthalmoplegia group: 1) initial brain injury; 2) brain stem lesions, cerebellar lesions, subarachnoid hemorrhage, or head trauma, which are commonly associated with external ophthalmoplegia; 3) no history of ophthalmic disease; 4) able to walk with supervision; 5) at least 21 points in Hasegawa's Dementia Scale-Revised (HDS-R), and no obvious cognitive impairment; and 6) external ophthalmoplegia with diplopia. 4) and 5) were added to the condition in order to control motor and cognitive functions between the groups. External ophthalmoplegia in this study focused on horizontal paralysis; subjects with vertically oriented paralysis were excluded. The criteria for external ophthalmoplegia included a deviation of at least 5° in the eye position on the affected side compared to the healthy eye (strabismus angle), and diplopia exhibited during median vision or horizontal vision on the paralyzed side. For the control group, patients who were admitted to the convalescent ward of Hospital A during a three-year period from January 2016 to December 2019 and who met the selection criteria 1) to 5) of the external ophthalmoplegia group but without external ophthalmoplegia, were selected.

3. Research methods

3.1 Research procedures

Age, time since onset, gender, diagnosis, Berg Balance Scale (BBS), HDS-R, and FIM motor items of the subjects were investigated retrospectively. The above data were extracted from those measured at the time of admission. The evaluation of FIM at Hospital A was done after discussions in other departments based on behavioral observations by ward nurses. For those with external ophthalmoplegia, we investigated the nine gazes photograph of the eye position measured at the time of admission, the results of the Hess red-green test, and the presence or absence of diplopia from the medical records kept by an ophthalmologist. Based on the nine gazes photograph, we measured the maximum tracking distance in the direction of the paralysis using the eye movement analysis software HAS-XViewer (DITECT Co., Ltd., Tokyo, Japan). The obtained distances were converted to angles using Hirschberg's method [4], and the differences between the affected and unaffected eyes were considered as the values of the strabismus angle. Those who underwent the Hess red-green test adopted the strabismus angle of the test results. We investigated whether the presence or absence of diplopia occurred in the median or only in the paralyzed directional vision.

3.2 Analytical methods

a) Baseline comparison between groups

Baseline examinations were conducted by comparing the external ophthalmoplegia group and control group with respect to age, time since onset, gender, diagnosis, BBS, and HDS-R using statistical processing.

b) Association between degree of external ophthalmoplegia and FIM

The correlation between strabismus angle and the total points in FIM motor items of the external ophthalmoplegia group was checked with statistical processing, and the association between the degree of external ophthalmoplegia and degree of ADL independence was examined.

c) FIM comparison between groups

The median of 13 FIM motor items and total points in the external ophthalmoplegia group and control group were compared by statistical processing. Statistical methods included the Mann-Whitney *U* test, Fisher's exact test, and Spearman's rank correlation coefficient. The analysis software used was JMP Pro Version 15. $p < 0.05$ was considered statistically significant.

3.3 Ethical procedure

This study was conducted after obtaining approval from the clinical trial review board of the affiliated facilities (F2021C010).

Results

1. Baseline comparison between groups

Thirty-four patients in the external ophthalmoplegia group and 44 patients in the control group were selected as the study subjects based on the selection criteria. There were no significant differences between the external ophthalmoplegia group and the control group in terms of age, time since onset, gender, diagnosis, BBS, and HDS-R at admission (Table 1).

2. Association between degree of external ophthalmoplegia and FIM

Table 2 shows the breakdown of the external ophthalmoplegia group. Figure 1 shows the association between the angle of strabismus and the total FIM motor score. Strabismus angle and total FIM score were significantly negatively correlated, and greater strabismus angle tended to be associated with lower ADL independence ($r = -0.41$, $p = 0.02$).

3. FIM comparison between groups

The median total FIM motor score was 76 points in the external ophthalmoplegia group and 83 points in the control group, and those with external ophthalmoplegia had lower ADL independence than those without ($p = 0.01$). In the detailed items, the

Table 1. Baseline comparison between groups.

		External ophthalmoplegia group (*n*=34)	Control group (*n*=44)	*p*-Value	Amount of effect
Age (years)[†]	—	61.5±15.9	69.9±12.5	0.26[†1]	0.13
Time from onset (weeks)[†]	—	6.9±3.7	7.2±2.8	0.68[†1]	0.05
Gender (name)	Man	19	27	0.65[†2]	0.65[†2]
	Woman	15	17		
Diagnosis (name)	Brainstem lesions	16	13	0.43[†2]	0.19
	Cerebellar lesions	3	6		
	Subarachnoid hemorrhage	11	16		
	Head injury	4	9		
BBS (points)[†]	—	45.7±6.9	47.7±5.0	0.13[†1]	0.17
HDS-R (points)[†]	—	26.7±2.8	26.7±2.7	0.86[†1]	0.02

BBS, Berg Balance Scale; HDS-R, Hasegawa's Disability Scale-Revised.
[†], mean ± standard deviation; [†1], Mann-Whitney *U*-test; [†2], Fisher accuracy test.

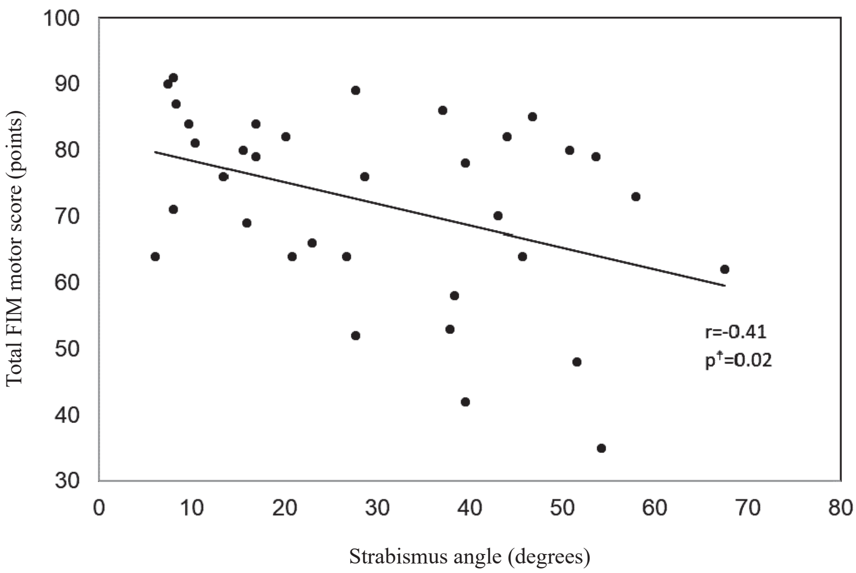

Figure 1. Degree of external ophthalmoplegia and total FIM motor score.
Degree of external ophthalmoplegia is assessed using the strabismus angle calculated from the difference between the affected and unaffected eyes. The larger the strabismus angle, the lower the total FIM motor score.
[†] Spearman's Rank Correlation Coefficient

Table 2. Breakdown of external ophthalmoplegia group.

		External ophthalmoplegia group (*n*=34)
Paralyzed eye (name)	Right	19
	Left	15
Paralysis direction (name)	Adduction	18
	Abduction	16
Skew angle (degree) [†]	—	30.0±17.5
Direction of diplopia (name)	Median vision	22
	Paralysis direction only	12

[†], mean ± SD.

independence level of the external ophthalmoplegia group was significantly lower in bathing, dressing (lower body), toileting, transfer to the chair, transfer to the toilet, transfer to the bathroom, and locomotion (walking) (Table 3).

Discussion

This case-control study examined the association between external ophthalmoplegia with diplopia due to brain injury and FIM motor items. As a result, compared to those who did not have external ophthalmoplegia with diplopia, total FIM motor scores and level of independence in terms of bathing, dressing (lower body), toileting, transfer to the chair, transfer to

Table 3. Comparison of FIM motor items between groups.

	External ophthalmoplegia group	Control group	*p*- Value[†1]	Effective dose
Eating	7	7	0.08	0.20
Grooming	7	7	0.61	0.06
Bathing	5	7	0.01	0.28
Dressing (upper body)	6	7	0.18	0.15
Dressing (lower body)	5	7	0.00	0.33
Toileting	6	7	0.00	0.32
Bladder management	7	7	0.27	0.13
Bowel management	7	7	0.35	0.11
Transfer to the chair	5.5	7	0.01	0.28
Transfer to the toilet	5	7	0.01	0.29
Transfer to the bathroom	5	6	0.00	0.36
Locomotion (walking)	5	6	0.00	0.37
Stairs	5	5	0.95	0.01
Total	76	83	0.01	0.29

Median FIM values are shown.
[†1], Mann-Whitney *U*-test.

the toilet, transfer to the bathroom, and locomotion (walking) were significantly lower. Furthermore, there was a significant negative correlation between the degree of external ophthalmoplegia and total FIM score.

Major neural mechanisms for eye movement reside in the dorsal brainstem and are longitudinally located over the midbrain, pons, and medulla oblongata [5, 6], and controlled by Paramedian Pontine Reticular Formation (PPRF) and Medial Longitudinal Fasciculus (MLF) [7]. This study focused on patients with brainstem lesions, cerebellar lesions, subarachnoid hemorrhage, and head trauma. We believe that the patients presented with horizontal external ophthalmoplegia due to direct damage to the horizontal oculomotor center in brainstem lesions, dorsal pontine effects due to hematoma or edema in cerebellar lesions, dorsal brainstem compression due to subarachnoid hemorrhage, abducens nerve palsy due to rupture of vertebral artery reservoirs [8, 9], or head trauma and injury to either of these horizontal oculomotor systems.

Previous studies on the association between hospitalized cerebral injuries and ADL independence in convalescent wards have reported correlations with balance functions [10], cognitive function (Mini Mental State Examination, MMSE) [11], healthy lower extremity muscle strength [12], nutritional status [13], and number of units in rehabilitation [14]. There were no previous reports showing the association between external ophthalmoplegia and ADL independence of people with convalescent brain injury. As such, the findings in this study are new. Bathing, dressing (lower body), toileting, transfer to the chair, transfer to the toilet, transfer to the bathroom, and locomotion (walking) exhibited correlations with external ophthalmoplegia accompanied by diplopia. All of these items involve movement in the standing position. The median score of these items in patients with external ophthalmoplegia was around 5 points and remained at the monitoring level. Diplopia is caused by horizontal external ophthalmoplegia, resulting in impaired sense of distance from the outside world, decreased safety such as grasping obstacles, and decreased attention to one's own body due to increased attention to vision. These problems are particularly seen in dynamic tasks [1]. Patients with external ophthalmoplegia in this study had a mean BBS of 45.7 points, and the ability to perform standing movements safely when using handrails and more, but tended to remain at the monitoring level due to the abovementioned problems.

Since the degree of external ophthalmoplegia was negatively correlated with the total motor item score, the degree of ADL independence might increase by reducing external ophthalmoplegia. The general treatment of external ophthalmoplegia is to follow up the patient for about six months while considering the use of a cycloptic occlusion with an eye patch, prism glasses, and the compensation method by head repositioning. If no improvement is shown, surgery may be considered [15]. There are some facilities where orthoptists provide eye movement training, but there are no reports of interventions by orthoptists in the convalescent ward. Reports of rehabilitation practices have described the effects of intervention studies that use a computer to promote basic eye movements [16−18]. Various assessment batteries have shown intervention effects, such as comfort in reading, and visual attention function, in addition to improving the range of motion and smoothness of eye movements. Reported effects also include training effect specialized for follow-up [19], intensive intervention of convergence [20], forced use of paralyzed eye [21], and effect of repeated facilitation therapy [22]. There are also practical reports with demonstrated effects of training using follow-up, fixation, saccade, and convergence for people with convalescent brain damage [23−25]. We believe that there is a need to consider active rehabilitation interventions for external ophthalmoplegia to increase ADL independence.

The limitations of this study are as follows. First, the extraction period of the external ophthalmoplegia group and control group were different, and there might have been differences in the environment surrounding the subject. Second, the control items associated with FIM, such as the number of rehabilitation units performed between groups, had not been confirmed. Third, since the subjects were able to walk under supervision and had no clear cognitive decline, people with low FIM during hospitalization were not examined. Fourth, it is possible that the subjects might have undergone cycloptic occlusion for external ophthalmoplegia, which limits the interpretation of association with ADL. In the future, it is necessary to perform rehabilitation for extraocular muscle paralysis and verify whether it is effective in improving ADL.

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