HUMAN BIOLOGY
2025, VOL. 95, ISSUE 3
ORIGINAL ARTICLE

OPEN ACCESS

Treatment Options for Traumatic Abducens Nerve Injury: A Dual-Center Clinical Experience

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ABSTRACT

Objective: This study aimed to assess the therapeutic efficacy of surgical and conservative treatments in patients with traumatic abducens nerve injury on neurofunctional recovery based on dual-center clinical experience.

Methods: A retrospective analysis was conducted on the clinical data of 71 patients with traumatic abducens nerve injury. Patients were categorized into the operation group and the conservative treatment group based on whether patients underwent surgical intervention during their hospitalization. A comparison was made between the two groups regarding ocular motility recovery before and after treatment. In addition, patients were further divided into complete paralysis and incomplete paralysis groups based on their initial ocular position score for subgroup analysis.

Results: The overall effective rate of conservative treatment group was 81.82%, while the overall effective rate of operation group was 88.89%. there is no statistically significant difference ($\chi2=0.173$, $P=0.678$) between two groups. Subgroup analysis indicated that both in the conservative treatment group and in the surgical group, the efficacy rate is significantly lower in the complete paralysis subgroup compared to the incomplete paralysis subgroup. Results showed the total effective rate was 92.31% vs .66.67% ($\chi2=4.70$, $P<0.05$) on conservative treatment group and 100% vs .66.67% ($\chi2=3.857$, $P<0.05$) on operation group.

Conclusion: The total effectiveness rate of the conservative treatment group was similar to that of the operation group, suggesting no difference in treatment effectiveness between two treatment plans, and the prognosis of traumatic abducens nerve injuries remains favorable. However, the higher the initial ocular position score of the patient, the more severe the paralysis symptoms, and the worse the treatment effect. Thus, treatment choices should be individualized to ensure optimal results.

INTRODUCTION

The abducens nerve, which is the sixth cranial nerve, innervates the lateral rectus muscle of both eyes, controlling the outward movement of the eyeballs Alkhatib et al. (2023). Over 10% of abducens nerve palsies result from trauma, with approximately 1% to 2.7% of patients with cranial nerve damage following head trauma experiencing involvement of the abducens nerve Fawaz et al. (2023), Heo et al. (2023). The abducens nerve enters the orbit via the superior orbital fissure and has a relatively long course along the skull base, making it particularly susceptible to injury during cranial trauma. Additionally, due to its proximity to the internal carotid artery within the cavernous sinus, increased intracranial pressure following head trauma can also affect the abducens nerve Sharma et al. (2016). Following abducens nerve injury, mild symptoms may include limited outward gaze and diplopia, while severe cases can lead to complete inability to abduct the eye, compensatory head posture, dizziness, and unsteady gait, significantly impacting the patient's quality of life Lee et al. (2020), Ravindran et al. (2017).

There is currently no unified standard for the treatment of the traumatic abductor nerve injury Tayebi Meybodi et al. (2018). In the early stages, drugs functioned as nourishing nerves, lowering blood pressure, and dilating blood vessels are often chosen for treatment, but the expected therapeutic effects are often not achieved. In some cases, while imaging suggests compression of the abducens nerve by bone fragment, a small surrounding hematoma, or if there is persistent elevation of intracranial pressure, early consideration should be given to performing abducens nerve decompression surgery Fam et al. (2015). However, many questions remain unanswered in clinical practice, such as the

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Keywords: Traumatic abducens nerve injury; ocular position score; surgery; corticosteroid pulse therapy.

efficacy of surgery, indications for surgery, and the optimal timing of surgical intervention. Additionally, some emerging treatments, such as stem cell therapy and neurotrophic factor therapy, are showing promising results Hariharan et al. (2018), Geressu et al. (2021).

Due to the prolonged self-repair period following abducens nerve injury, neurological dysfunction often persists. For neurosurgeons, having clear and effective treatment strategies for abducens nerve injury and reducing treatment duration is of paramount importance. Based on this, we conducted a retrospective analysis of 71 patients with traumatic abducens nerve injury who underwent treatment at the Department of Neurosurgery in the Zhangjiajie People's Hospital of Hunan Province and Xiangya Changde Hospital of Hunan Province from January 2021 to December 2023, comparing the efficacy of surgical and conservative treatments, aiming to determine the optimal treatment approach.

METHODS

Participants

We collected clinical data from 71 patients diagnosed with traumatic abducens nerve injury who received treatment at the Department of Neurosurgery in both Zhangjiajie People's Hospital of Hunan Province and Xiangya Changde Hospital of Hunan Province between January 2021 and December 2023. The inclusion criteria were as follows: (1) binocular diplopia; (2) a clear history of head trauma; (3) diagnosed with unilateral abducens nerve palsy; (4) undergone treatment for at least two weeks; (5) clear consciousness and stable vital signs; (6) age over 18 years. Exclusion criteria are as follows: (1) muscle disorders caused by thyroid dysfunction, myasthenia gravis, or other diseases; (2) congenital strabismus; (3) concurrent paralysis of the trochlear nerve or oculomotor nerve; (4) coma or inability to cooperate.

For all included cases, we documented the initial ocular position score, gender, age, injured side, cause of injury, treatment plan, treatment duration, and recovery status of eye movement. All methods were conducted in accordance with relevant guidelines and approved by the Ethics Committees of the Zhangjiajie People's Hospital of Hunan Province and Xiangya Changde Hospital of Hunan Province.

Diagnosis

The diagnosis of traumatic abducens nerve injury was based on the patient's history of trauma, symptoms, and imaging examination results Koshy et al. (2022). The diagnosis of the condition is based on the inability of the affected eye to perform outward gaze or limited outward gaze function, with the affected eye deviating towards the nose. Additionally, the patient presents with diplopia and may exhibit compensatory head posture.

Grouping

All 71 patients included in the study met the clinical diagnostic criteria for traumatic abducens nerve injury, with a history of head and facial trauma. Patients who underwent surgical treatment were categorized into the operation group, while those who did not undergo surgical treatment but instead received steroid pulse therapy supplemented with supportive treatment were classified into the conservative treatment group. All patients' initial ocular position scores will be recorded and used for subgroup analysis. The ocular position score is determined using the eye movement grading method in the Ocular Motor Nerve Palsy Scale to assess the degree of abduction impairment in patients during their visit Zhou et al. (2018). A higher score indicates more severe impairment. Complete paralysis is defined as an ocular movement score of 3 or 4 points, where the center point of the pupil does not reach the midpoint between the inner and outer canthi when attempting maximal abduction.

Management

For patients in the conservative treatment group, high-dose corticosteroid pulse therapy was typically employed. Initially, within 3-8 hours post-injury, 500mg of methylprednisolone was administered, followed by a 3-day continuous pulse therapy with the dosage adjusted to 300mg, then further adjusted to 100mg after 3 days. Meanwhile, they were supplemented with diuretics, neurotrophic agents, vasodilators, and hyperbaric oxygen therapy.

For patients in the operation group, surgical interventions were performed to decompress the abducens nerve. Surgical procedures include both intracranial and extracranial decompression of the abducens nerve, as well as endoscopic trans-nasal decompression. The objective of these surgeries is to alleviate compression on the abducens nerve and facilitate recovery of its function. Following surgery, patients receive antimicrobial therapy, dehydration treatment, vascular nutritional support, and other supportive measures.

Measurements

Based on reference Zhou et al. (2017), the efficacy assessment criteria are formulated as follows: Cured: After treatment, the affected eye exhibits unrestricted outward movement, with no strabismus or diplopia when looking straight ahead, and there is no visual field defect.

Marked effective: After treatment, the affected eye exhibits essentially unrestricted outward movement, with no strabismus when looking straight ahead, and the angle of diplopia is less than 30°, and the visual field is basically normal.

Effective: After treatment, there is slight improvement in

the outward movement of the affected eye, and there are varying degrees of improvement in the strabismus and diplopia when looking straight ahead, with an increase in the visual field compared to before treatment.

Ineffective: After treatment, there is no significant change in the outward movement of the affected eye, and there is no change in diplopia, strabismus, or visual field defect.

The overall effective rate is calculated as follows: (Number of cured cases + Number of significantly improved cases + Number of effective cases) / Total number of cases × 100%.

Statistical analysis

Statistical analysis was conducted using SPSS version 26 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as mean ± standard deviation (X±S). The t-test was utilized to compare the mean values of continuous variables between two groups. Categorical variables are presented as percentages (%) and were compared between groups using the chi-square test to determine treatment efficacy. A p-value less than 0.05 was considered statistically significant.

RESULTS

Baseline characteristics of patients

This study collected a total of 71 cases of traumatic abducens nerve palsy, including 46 males and 25 females. Among them, 38 cases involved the left eye and 33 cases involved the right eye. Imaging examinations such as head CT and MRI suggested intracranial hemorrhage in 31 cases and orbital fractures in 22 cases. Upon initial presentation, the eye position score was 4 points in 19 cases, 3 points in 17 cases, 2 points in 27 cases, 1 point in 8 cases. Complete paralysis was observed in 36 cases while incomplete paralysis in 35 cases. The onset age ranged from 20 to 66 years, with a mean age of 38.95±13.09 years in conservative treatment group and 38.15±9.82 years in operation group. The results in Table 1 indicate that there were no statistically significant differences (P>0.05) in gender, age, laterality of eye involvement, or initial ocular position score between two groups, suggesting comparable baseline characteristics between two groups.

Table 1: Baseline characteristics of patients

	Patients	Sex (male/female)	Age (x^-±s)	Side (left/right)	ocular position score (complete/ incomplete paralysis)
Conservative treatment group	44	28/16	38.95±13.09	25/19	18/26
Operation group	27	18/9	38.15±9.82	13/14	18/9
χ^2 /t	-	0.067	0.276	0.506	3.471
P valve	-	0.795	0.784	0.477	0.062

Comparison of therapeutic effects between conservative treatment group and operation group

The overall effective rate of conservative treatment group was 81.82%, with 9 patients cured, 15 patients showed marked effective, 12 patients showed effective and 8 patients showed ineffective.

The overall effective rate of operation group was 88.89%, with 7 patients cured, 9 patients showed marked effective, 5 patients showed effective and 6 patients showed ineffective. No statistically significant difference ($\chi2$=0.173, P=0.678, Table 2) between two groups.

Subgroup analysis: Comparison of ocular position score on therapeutic effects

Among the patients received conservative treatment, 18 patients' initial ocular position score were no less than 3 and were diagnosed as complete paralysis, with 26 patients' initial ocular position score were less than 3 and were diagnosed as incomplete paralysis.

The overall effective rate of the incomplete paralysis group was higher than that of the complete paralysis group, with a statistically significant difference ($\chi2$=4.70, P<0.05, Table 3). Among the patients received operation, 18 patients were diagnosed as complete paralysis and 9 patients were diagnosed as incomplete paralysis. There was still statistically significant difference in the overall effective rate between two groups ($\chi2$=3.875, P<0.05, Table 4).

Table 2: Comparison of therapeutic effects between conservative treatment group and operation group.

	Patients	Cure (%)	Marked effective (%)	Effective (%)	Ineffective (%)	Total effective rate (%)
Conservative treatment group	44	9 (20.45%)	15(34.09%)	12 (27.27%)	8 (18.18%)	81.82%
Operation group	27	7 (29.63%)	9(25.93%)	5 (33.33%)	6 (11.11%)	88.89%
			χ^2=0.173, P=0.678			

Table 3: Comparison of ocular position score on conservative treatment group

	Patients	Cure (%)	Marked effective (%)	Effective (%)	Ineffective (%)	Total effective rate (%)
Complete paralysis group	18	3 (16.67%)	4(22.22%)	5 (27.78%)	6 (33.33%)	66.67%
Incomplete paralysis group	26	6 (23.08%)	11(42.31%)	7 (26.92%)	2 (7.7%)	92.31%
			χ2=4.70, P<0.05			

Table 4: Comparison of ocular position score on operation group

	Patients	Cure (%)	Marked effective (%)	Effective (%)	Ineffective (%)	Total effective rate (%)
Complete paralysis group	18	4 (22.22%)	5(27.78%)	3 (16.67%)	6 (33.33%)	66.67%
Incomplete paralysis group	9	3 (33.33%)	4(44.44%)	2 (22.22%)	0 (0%)	100%
			χ2=3.857, P<0.05			

DISCUSSION

The abducens nerve originates from the cerebral cortex, descends to the brainstem nuclei, and then emits secondary neuronal fibers to innervate the lateral rectus muscle of the eye Azad et al. (2016), Asproudis et al. (2015). Lesions affecting the horizontal gaze center in the pons, as well as lesions in the cerebral cortex and cortical gaze center, can result in paralysis of the extraocular muscles Serio et al. (2019). Due to its relatively long intracranial course, traumatic injury leading to abducens nerve damage is the most common type of peripheral ocular muscle paralysis. After exiting the skull, the abducens nerve traverses the surface of the petrous part of the temporal bone, running between the dura mater and the petrous bone, and then makes a right-angled bend to enter the cavernous sinus Hofer et al. (2015), Bakhsheshian et al. (2016). This segment of its course is relatively fixed at both ends with little room for movement, making it prone to injury. The abducens nerve must exit the skull through the skull base foramen, which makes it susceptible to injury if the skull base is traumatized and affects the foramen, leading to abducens nerve damage. Skull fractures themselves can cause traction and contusion injuries to intracranial nerves or disrupt the blood supply to cranial nerves due to fracture-related issues, thereby resulting in impairment of the abducens nerve Wysiadecki et al. (2015), Ding et al. (2024).

Abducens nerve palsy can be classified according to its etiology into ischemic, compressive, traumatic, and non-specific inflammatory types. Ischemic abducens nerve palsy is often associated with conditions such as diabetes mellitus, hypertension, hyperlipidemia, and a history of cerebrovascular accidents Novotny et al. (2021), Tsai et al. (2021). Compressive abducens nerve palsy resulting from intracranial space-occupying lesions typically involves lesions near the abducens nerve nucleus or in close proximity to its fibres Revuelta Barbero et al. (2019). Traumatic abducens nerve palsy is the most common type encountered by neurosurgeons and is often associated with a clear history of trauma. Among our group of cases, car accidents accounted for 32 cases (45.07%), fights for 20 cases (28.17%), falls for 12 cases (16.90%), and other causes for 7 cases (9.9%).

Damage to the abducens nerve results in weakness of the innervated lateral rectus muscle, leading to exotropia or diplopia, and severe cases may present with compensatory head posture. Unilateral abducens nerve palsy is more common than bilateral cases and presents with either complete or partial paralysis Paiva et al. (2016). Symptoms include esotropia of the affected eye, restricted or absent outward eye movements, compensatory head tilting toward the affected side, and fixation of the gaze toward the unaffected side. Diplopia is pronounced. In severe cases, walking may require occlusion of one eye Bansal et al. (2015).

Currently, there is still controversy surrounding the treatment approach for traumatic abducens nerve injuries San-juan et al. (2014), Li et al. (2016). Some physicians advocate for early surgical intervention, especially for patients with bone fragments or small hematomas compressing the abducens nerve, suggesting early decompression surgery. However, other physicians believe that most cases of abducens nerve palsy can recover gradually without surgery, and instead, conservative treatment options such as steroid therapy and neurotrophic drugs can be pursued McDowell et al. (2020). Steroids have been validated for their significant role in treating nerve injuries.

Corticosteroids, such as prednisone or methylprednisolone, are often used in the management of traumatic abducens nerve injury. In acute nerve injuries, there is often inflammation and swelling around the injured abducens nerve, which can exacerbate tissue damage and impede nerve recovery. Corticosteroids help to reduce this inflammation, potentially minimizing tissue damage and promoting a more favourable environment for nerve regeneration Jain et al. (2020). In addition to their anti-inflammatory effects, corticosteroids may also help prevent secondary damage to nerves. After an initial injury, there can be a cascade of biochemical events that lead to further damage to nerve tissue. Corticosteroids may help to interrupt or mitigate this cascade, limiting the extent of secondary damage Mata Moret et al. (2019).

Corticosteroids are typically administered intravenously in acute nerve injury cases. The dosage and duration of treatment may vary depending on the severity of the injury, individual patient factors, and the neurosurgeon's clinical judgment. A typical regimen might involve an initial high dose followed by a tapering course to gradually reduce the dose over time.

For patients with evident bone fragments and hematomas compressing the abducens nerve, surgical treatment can be considered. Preoperative assessment through imaging studies and electrophysiology helps identify the site of nerve injury Salunke et al. (2016). Surgery can be performed via intracranial or extracranial approaches, where bone fragments compressing the nerve are removed using drilling techniques, hematomas around the nerve are evacuated, and the outer membrane of the nerve is incised under a microscope to achieve decompression. Endoscopic trans-nasal decompression surgery for the abducens nerve has also been utilized. Some institutions have started performing microvascular decompression for the abducens nerve Borg et al. (2020). Currently, there are no randomized controlled studies evaluating the efficacy of different surgical techniques, so the primary criterion for selection remains the proficiency of the clinical surgeon Jecko et al. (2020).

Our research findings also indicate that there is no significant difference in efficacy between the operation group and the conservative treatment group. The effectiveness rate in the surgical group was 88.89%, while it was 81.82% in the conservative treatment group ($\chi 2=0.173$, $P=0.678$). Overall, the prognosis of traumatic abducens nerve injuries remains favorable. Based on our clinical experience, for patients with evident bone fragments and hematomas compressing the abducens nerve, surgical treatment should be preferred to relieve the compressed abducens nerve and salvage its function as early as possible. However, for cases where there is no apparent compression of the abducens nerve, the efficacy of surgery may be less significant. Furthermore, some studies have indicated that the combined effect of nerve decompression surgery and steroid treatment is more beneficial.

Besides, our research has found that patients with higher ocular position scores tend to have more severe symptoms of abducens nerve palsy, and consequently, poorer treatment outcomes. Patients with a ocular deviation score of 3 or above at the time of diagnosis usually have a worse prognosis. This score represents the extent of outward deviation impairment in patients, with higher scores indicating greater ocular misalignment and more severe conditions, leading to poorer treatment outcomes. Subgroup analysis results demonstrate that both in the conservative treatment group and the surgical group, the

efficacy rate is significantly lower in the complete paralysis subgroup (ocular deviation score of 3-4) compared to the incomplete paralysis subgroup (ocular deviation score below 3). Results showed the total effective rate was 92.31% vs .66.67% ($\chi2=4.70$, $P<0.05$) on conservative treatment group and 100% vs .66.67% ($\chi2=3.857$, $P<0.05$) on operation group. This may be due to an increase in energy production by surviving neurons, with a reduction in acidic metabolic by-products, which in turn self-corrects the imbalance of ions both inside and outside the cells.

This process accelerates the regeneration of capillaries and the establishment of collateral circulation, providing damaged nerve tissue with ample nutritional substances, thereby promoting the repair of its own nerve fibers and myelin sheaths. Furthermore, compared to complete paralysis, incomplete paralysis of the abducens nerve still partially innervates the lateral rectus muscle and retains some degree of activity. This helps prevent tissue atrophy and facilitates early restoration of its activity, thereby promoting nerve function recovery.

In addition, for patients with strabismus symptoms that are refractory to conservative treatment or decompression surgery, consideration could be given to referring the patient to ophthalmology for corrective surgery after 6-8 months Moon et al. (2019), Dimou et al. (2021). The aim is to achieve visual recovery and promote normal ocular alignment.

Traditional corrective surgeries in clinical practice have gradually been phased out with the development of scientific technology due to risks such as anatomical layer disruption and misalignment of incisions, leading to poor treatment outcomes and a higher likelihood of postoperative complications.

However, in recent years, the emergence of minimally invasive surgeries has addressed the shortcomings of traditional surgeries Han et al. (2023). Commonly used procedures include Jensen's procedure, Hummelsheim's procedure, and Brooks' procedure. Microscopic medial rectus transposition surgery is a safe and effective procedure for treating patients with exotropic strabismus caused by complete paralysis of the abducens nerve.

CONCLUSION

The total effectiveness rate of the conservative treatment group was similar to that of the operation group, suggesting no difference in treatment effectiveness between two treatment plans, and the prognosis of traumatic abducens nerve injuries remains favorable. However, the higher the initial ocular position score of the patient, the more severe the paralysis symptoms, and the worse the treatment effect. Thus, treatment choices should be individualized to ensure optimal results.

DECLARATIONS

Acknowledgements

We are grateful to the participating patients.

Author disclosure statement

No conflict of interest.

Data availability

The datasets used and analysed during the current study available from the corresponding author on reasonable request.

Ethical Approval

The study was approved by the Ethics Committees of the Zhangjiajie People's Hospital of Hunan Province and Xiangya Changde Hospital of Hunan Province. Informed written consent for study participation was obtained from all patients.

Competing interests

No competing financial interests exist.

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