Original Article

Role of delayed wider endoscopic optic decompression for traumatic optic neuropathy: a single-center surgical experience

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Background: The aim of the present study was to discuss the efficacy of delayed wider endoscopic optic decompression in traumatic optic neuropathy (TON).

Methods: A total of 479 patients were treated with corticosteroids and delayed wider endoscopic optic decompression, including the injury-to-surgery interval, within 2 weeks in patients with no light perception (NLP), and within 1 month in patients with residual eyesight. Based on the traditional decompression range, the superior wall of the optic canal was further decompressed. The preoperative and postoperative visual acuities (VAs) were reviewed, and the therapeutic efficacy was analyzed.

Results: The final VA was 0.1 or better in 29 cases, finger count in 79 cases, hand motion in 99 cases, light perception (LP) in 25 cases, and NLP in 247 cases. A total of 136 patients (136/383, 35.5%) recovered after NLP treatment, and 78 patients (69/96, 71.9%) had improved residual eyesight. The improvement rate in patients with residual eyesight was significantly higher than that of patients with NLP ($P<0.01$). Moreover, the total VA after treatment was better than that before surgery ($P<0.01$).

Conclusions: Delayed wider optic nerve decompression plus corticosteroids remains an effective and safe therapeutic strategy for patients with delayed treatment intervals of more than 1 week, especially for those with residual eyesight within 1 month.

Keywords: Traumatic optic neuropathy (TON); corticosteroids; delayed wider decompression; follow-up

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Introduction

Traumatic optic neuropathy (TON), including direct and indirect damage, remains an important cause of traumatic visual loss following closed head injury. It has an incidence of 0.5–5%, and is more common in cases of craniofacial fracture (1-4). Direct injury is caused by direct penetration of the nerve by a foreign body and a displaced optic canal fracture. It is also the result of the impact of external force transmitted into the optic canal, followed by injury to optic nerve axons, increased intracanalicular pressure, and vascular ischemia, resulting in secondary retinal ganglion cell (RGC) loss (5,6).

To date, there is little consensus on the optimal treatments for TON. A variety of treatment strategies have been studied, including observation, corticosteroid therapy, and surgical decompression of the optical nerve canal with or without corticosteroid therapy (7-10).

Theoretically, endoscopic optic nerve decompression (EOND) and corticosteroids are useful for decreasing

Table 1 Clinical manifestations and examination results of patients with traumatic optic neuropathy

Characteristics	Number (%)
Sex	
Male	432 (90.2)
Female	47 (9.8)
Age (years	28.5±12.92
Cause	
Motor accident	338 (70.6)
Fall	87 (18.2)
Crushing blow	38 (7.9)
Other	16 (3.3)
Eyesight	
No light perception	383 (80.0)
Light perception	29 (6.1)
Hand motion	36 (7.5)
Finger count	31 (6.4)
Fundus examination	
Pale and edematous optic papilla	45 (9.4)
Normal optic papilla	434 (90.6)
High-resolution computed tomography	
Fracture of optic canal	403 (84.1)
No fracture of optic canal	76 (15.9)
Magnetic resonance imagine	
Hyperintensity of injured optic nerve	9 (39.1)
Normal optic nerve	14 (60.9)
Interval between trauma and surgery	
1–2 weeks	426 (88.9)
2 weeks–1 month	53 (11.1)

intracanalicular pressure and improving the delivery of nutrients to the optic nerve, which is critical for optic nerve function. However, many issues exist, such as surgical efficacy, operative indications, and surgical timing. Although the optimal timing of the operation is not clear, it is generally believed that the sooner the operation is performed, the better (11,12).

However, early surgery, especially within 3 days, is impractical for almost all patients in our hospital. Most patients in our department are transferred from other hospitals for surgical treatment after diagnosis, which results in surgery delays >1 week after the injury. A few studies have reported the effectiveness of delayed decompression within several weeks after injury, but these studies have small sample sizes and the results are questionable (13-15).

The aim of the present study was to discuss the efficacy and safety of delayed optic decompression with corticosteroids 1 week after the onset of injury in 479 TON patients. We present the following article in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/atm-20-7810).

Methods

Patients

A total of 479 patients with TON who underwent EOND with corticosteroids more than 1 week after injury at the Department of Neurosurgery, Tongren Hospital, from September 2008 to August 2017, were retrospectively analyzed. All patients were followed-up from 1 month to 46 months (average 10.8 months). Patients with bilateral TON or visual acuity (VA) better than 6/60 were excluded from the study. Additionally, blind patients who had been injured for more than 2 weeks or patients with residual vision for >1 month were not included.

All consecutive patients admitted to our hospital were diagnosed by impaired VA with an afferent pupillary defect in the involved eye after head injury. Full ophthalmologic examinations were undertaken to exclude post-traumatic globe disorders, such as open globe injury, traumatic cataract retinal detachment, and vitreous hemorrhage. High-resolution computed tomography (HRCT) scan was then performed with 1-mm sections through the optic canal to evaluate the orbit and optic canal. Optic nerve magnetic resonance imaging (MRI) scans were performed in 24 patients. The flash visual evoked potential was examined in 58 patients upon admission. The characteristics of patients with TON in the present study are shown in *Table 1*.

Treatment protocol

Upon admission to our department, all patients were treated with high-dose methylprednisolone (1,000 mg/day) intravenously for 3 days. No serious side effects occurred in our series. If the VA did not improve to 6/60 after steroid treatment, EOND was then suggested. EOND was

Table 2 VA of pretreatment and post-treatment among the different groups

VA pretreatment	VA post-treatment				
	NLP (n)	LP (n)	HM (n)	FC (n)	≥0.1 (n)
NLP [383]	247	19	78	38	1
LP [29]	0	6	13	7	3
HM [36]	0	0	8	21	7
FC [31]	0	0	0	13	18
Total [479]	247	25	99	70	29

FC, finger count; HM, hand motion; NLP, no light perception; VA, visual acuity.

performed on patients who agreed to undergo surgery. Oral vasodilators, intramuscularly injected with mecobalamin and hyperbaric oxygen, were administered for 2 weeks to improve VA following surgery. The present study was approved by the ethical committee of our hospital, and informed consent was obtained from each participant. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013).

Surgical technique

EOND surgery was performed under general anesthesia, with controlled hypotension after routine preparation. Soaked gauze with 0.1% adrenaline and 1% dicaine was used to constrict the blood vessels in the nasal cavity. Routine endoscopic ethmoidectomy and sphenoidotomy were performed first. The medial wall of the orbit and the orbital apex were confirmed and exposed. The orbital fasciae was protected from damage to prevent the herniation of intra-orbital fat blocking the operative cavity during surgery. The anterior wall of the sphenoid was then opened and enlarged, and the optic canal and carotid artery canal were identified. Under endoscopic observation, the medial, inferior, and superior walls of the bony optic canal were gently removed by a long hand microdrill with a diamond burr. Finally, the optic nerve sheath and the annulus of the Zinn ring were incised with a sharp sickle knife to expose the fasciculus opticus if necessary. In this case series, the incision was performed in only 38 patients who had intraoperative findings indicating obvious optic nerve swelling.

Visual assessments

In the present study, VA was the main assessment criterion to evaluate the efficacy of EOND during the course of treatment. VA was considered to have an increase of 1 line or more on the Snellen visual chart, or an improvement from no light perception (NLP) to light perception (LP) or better, from LP to hand motion (HM) or better, from HM to finger count (FC) or better, or from FC to 6/60 or better.

Follow-up visits were scheduled 1 week, 1 month, and 3 months after discharge, and submitted to examine VA. The evaluation of VA was performed by ophthalmologist.

The VA of 49 patients (10.2%) at discharge, and the VA of 64 patients (13.4%) at 1 month was chosen as the final result because of loss to follow-up.

Statistical analysis

The χ^2-test was used to compare the difference in surgical efficacy between patients with residual vision versus those with NLP prior to surgery. Wilcoxon rank and tests of 2 groups were used to compare preoperative and postoperative VAs.

All statistical analyses were performed using SPSS version 22.0 (IBM, Armonk, NY, USA), and $P<0.05$ indicated statistical significance.

Results

Clinical manifestations and examination data of patients are described in *Table 1*. A total of 479 patients with a diagnosis of TON underwent EOND in the present study (432 men and 47 women), with an age range from 6 to 61 years (average age 28.5±12.92 years). The main causes of TON were traffic accidents (338 cases), falls (87 cases), and crushing blows (38 cases). Transient loss of consciousness occurred in 91 cases. Of the 479 patients, 383 had NLP, 29 had LP, 36 had hand motion, and 31 had FC upon admission. The surgical timing from injury to surgery ranged from 7 to 31 days (average interval 11.8±4.92 days). A total of 426 patients underwent surgery within 2 weeks, and 53 patients underwent surgery within 1 month.

Of the 479 patients with TON, the final VA reached 6/60 or better in 29 patients, FC in 79 patients, HM in 99 patients, LP in 25 patients, and NLP in 247 patients. The postsurgical VA of different group was described in *Table 2*. The

Table 3 Comparison of presurgical eyesight and postsurgical eyesight in patients with TON

Group	NLP (n)	LP (n)	HM (n)	FC (n)	≥0.1	Total (n)
Preoperative	383	29	36	31	0	479
Postoperative	247	25	99	79	29	479

Z=–12.636, P=0.000. Significant difference between presurgical eyesight and postsurgical eyesight in patients with traumatic optic neuropathy (TON) (P<0.01). Postoperative visual acuity (VA) improved significantly compared with preoperative VA. Wilcoxon rank and tests of 2 groups were applied for the comparison of preoperative and postoperative values. FC, finger count; HM, hand motion; NLP, no light perception.

Table 4 Comparison of the postsurgical VA improvement rate in groups of traumatic optic neuropathy patients with different postoperative VAs

Group	Pretreatment	Improvement, post-treatment	VA improvement rate	χ^2	P value
NLP	383	136	35.5	41.466	0.000
No NLP	96	69	71.9		

Comparison of the postoperative visual acuity (VA) improvement rate between the preoperative VA with the no light perception (NLP) group, and the preoperative VA with the no NLP group. VA improvement rate was much better in the preoperative VA with residual VA group than that in the preoperative VA with NLP group; χ^2=41.466, P=0.00 (<0.01). The χ^2-test was applied to compare VA improvement between the 2 groups.

postsurgical eyesight was significant better than presurgical eyesight (P<0.01) (*Table 3*). Of the 383 patients with NLP preoperatively, VA recovered in 136 patients (35.5%); of these 136 patients, 19 patients improved to LP, 78 to HM, 38 to FC, and 1 to a VA of 6/60.

Of the 96 patients who retained residual eyesight from LP to residual eyesight <0.1 preoperatively, 69 (71.9%) improved after EOND. There was a significant difference of improvement rate between the group with NLP before surgery and the group with residual eyesight (P<0.01) (*Table 4*).

Four cases of cerebrospinal fluid rhinorrhea (CSFR) occurred during surgery. All cases of CSFR were repaired by mucosal flap transplantation (the mucosa from excised middle turbinate), and the patients were confined to bed for 7–10 days; all of the patients recovered without complications.

Eight patients developed massive hemorrhage during surgery. Tela iodoformum was immediately inserted into the sphenoid sinus to stop the bleeding, and patients were immediately followed by digital subtraction angiography (DSA) examination.

Of the 8 patients, 6 were diagnosed with carotid-cavernous fistula (CCF), and the other 2 patients were diagnosed with traumatic internal carotid artery aneurysm. Balloon embolization was used to treat CCF, and the Willis intracranial stent graft system (Microport, China) was used for traumatic internal carotid artery aneurysms. All patients were discharged with no deficit in neurological function.

Discussion

In this case series, 479 patients (432 men and 47 women) with a diagnosis of TON received corticosteroids and underwent EOND. The age range of the patients was 6–61 years (average age 28.5±12.92 years). The main causes of TON were traffic accidents (338 cases, 70.6%), falls (87 cases, 18.2%), and crushing blows (38 cases, 7.9%). Our data were consistent with those of previous studies (1,16-18). However, the main characteristic of the cases in the present study was the long-time interval;1 week to 1 month (11.8±4.92 days) from injury to surgery. The results revealed that decompression plus corticosteroid therapy was beneficial for improving the VA of TON with total visual loss within 7 days and partial visual loss within 1 month, especially for the latter.

EOND could be undertaken as a major treatment for TON due to its advantages, such as minimal invasiveness and excellent visibility. Based on our experience with EOND since 2006, in the present study, we proposed for the first time, further decompressing the superior wall of the optic canal on the basis of the traditional decompression range to achieve more adequate decompression, especially for patients with bone fractures or impingement of the

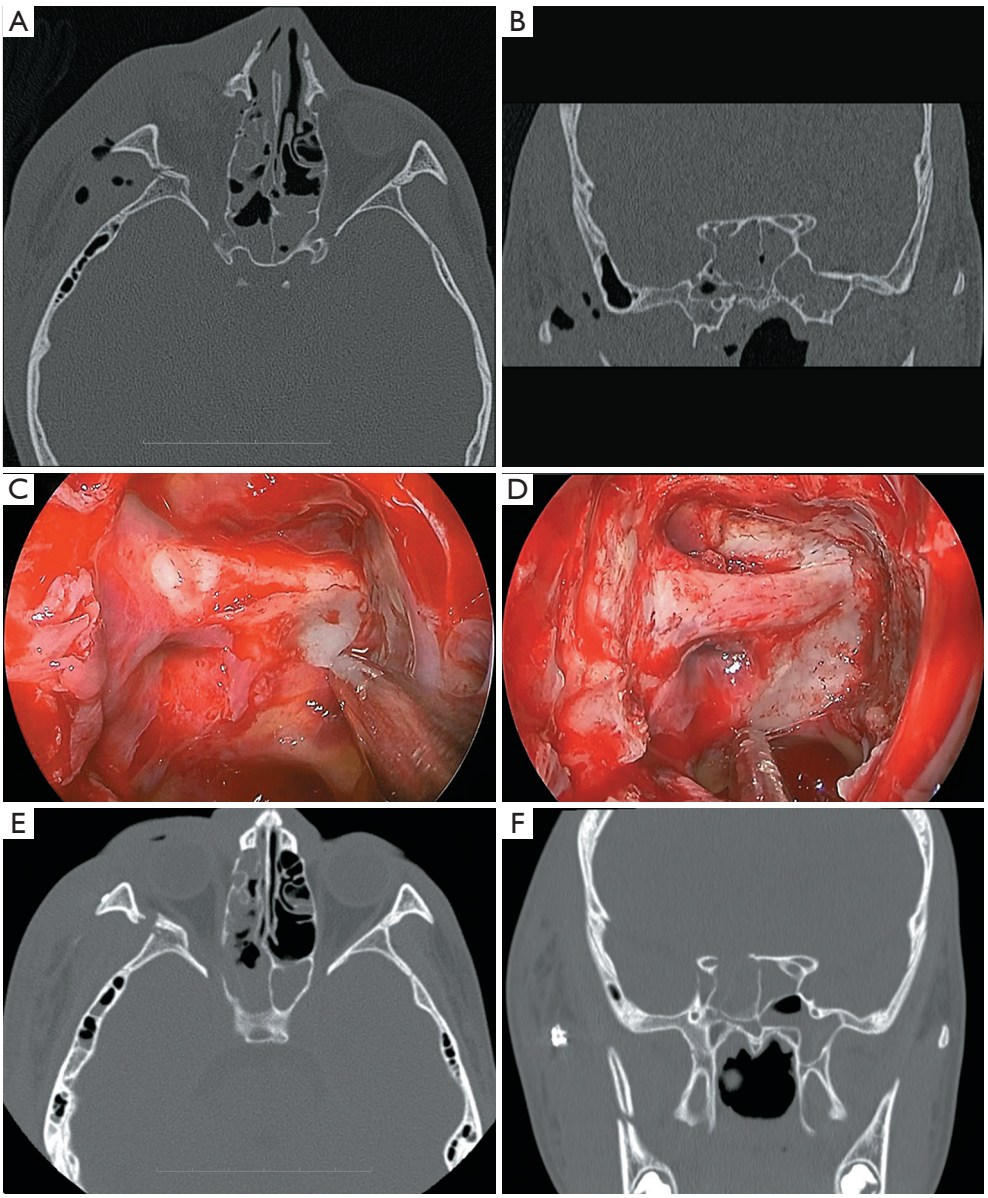

Figure 1 High-resolution horizontal (A) and coronal (B) scanning of the optic canal in a 11-year-old male with left traumatic optic neuropathy. Displacement of fractures from the planum sphenoidale and corresponding sphenoid hemosinus are evident. Intraoperative endoscopic image of the same patient (C) showed the fracture of the optic canal with no displacement. Wider optic decompression was performed, including the medial, inferior, and superior wall (D). Axial and coronal computed tomography scans (E,F) after surgery indicating decompression of the left optic nerve.

superior wall.

The optic nerve is easily damaged by blunt head trauma, especially in the intracanalicular segment, which is vulnerable to direct contusive forces on the optic canal and nerve or elastic deformations from surrounding bones. The bony fragments or hematomas can lead to secondary swelling of nerves in the bony canal, a decrease in blood supply, and finally, axon loss (19,20). The force-bearing points are commonly located at the regions anterior and lateral to the eyebrow.

Horizontal HRCT and coronal optic canal HRCT are essential for detecting fractures of the canal and paranasal

sinuses, with reported rates ranging from 6% to 92% (21). CT scans provide a road map for surgery, and revealing anatomic variations in the sphenoid sinus, optic canal, and ethmoid sinus, especially the carotid artery canal and optic canal. Furthermore, a CT-based scoring system or risk-factor analysis can be used to predict the severity of VA and the prognosis of treatment (22-25).

Fractures of the optic canal and hemorrhage in the posterior group of the ethmoid sinuses are regarded as radiological signs of TON. The sensitivity of CT scans is influenced by several factors, such as the scanner machine, the thickness of scanning, the selection of a baseline scan, and the experience of the physician. Although no fractures of optic canal in HRCT scans, fractures could be found and confirmed during surgery, with the rate for missed fractures ranging from 16.1% to 75% (26-28). Preoperative HRCT images showed that 398 patients (83.1%) had fractures of the optic canal, but another 38 patients (7.9%) were confirmed to have fractures of the optic canal during surgery. Therefore, linear fractures, fractures with slight displacement and abnormal anatomy of the optic canal, and adjacent structures are more likely to be misdiagnosed or missed. By now, 1-mm sections through the optic canal and indirect signs on CT scans such as hemorrhage in the posterior ethmoid sinuses or sphenoid sinus may help to reduce the misdiagnosis of mission, but there is no effective to avoid.

Conventional MRI often shows normal optic nerves in patients with TON, which was unable to exhibit consistency with the clinical symptoms. In our study, only 5 patients (5/24) showed hyperintensity in injured optic nerves. MRI with diffusion weighted imaging and diffusion tensor imaging partly reflected the microstructural changes in optic nerves of TON patients. The mean apparent diffusion coefficient (ADC) was significantly decreased and was correlated with poor VA (29,30).

However, a higher ADC and lower fractional anisotropy were obtained in another report, which might be due to the period from injury to examination (31).

Because of the low incidence and variable therapeutic strategies of TON, the current relevant literature mainly comprises retrospective cohort studies, and none of the treatments has been accepted as universal management (7,8,32,33). Although spontaneous recovery of VA was observed in some cases, treatments consisting of endoscopic transethmosphenoid optic canal decompression (ETOCD) with a combination of steroids were considered more effective (33,34).

Adequate depression of the optic canal is the key point of the surgical procedure, especially in areas where the optic nerve is compressed by bone fragments. Commonly, the medial and inferior walls of the optic canal are easily decompressed after exposure of the sphenoid sinus and orbital apex. However, the superior wall was difficult to remove because of the tight adherence to the dura of the anterior skull base. We began by gently grinding away the anterior cranial base, exposing the anterior cranial base dura, and then further grinding away the superior wall of the optic canal (*Figure 1*). Unlike the manipulation involved in removing the inferior and medial wall, the narrow space increased the occurrence of injuries to the dura and optic nerve. Although decompression of the superior wall might lead to a high risk of cerebrospinal fluid (CSF) leakage and injury to the brain tissues and arteries of the frontal lobe, it was avoidable by delicate actions using diamond drills by experienced surgeons. No CSF leakage or injury to the artery and subdural tissues occurred in our study during the decompression of the superior wall. Over the decompressive length of optic canal, the cranial and orbital foramens had to be fully decompressed, especially at the cranial foramen, which is prone to insufficient decompression.

Regarding the incision of the dural sheath in the surgical procedure, we do not advocate incising the dura sheath in all cases, only for patients with obvious hemorrhage and edema of the optic nerve. Indeed, such patients may be at risk of damage to the optic nerve or ophthalmic artery, CSF leakage, and secondary meningitis. Only 42 patients underwent incision of the sheath, even though no abovementioned complications occurred.

The time interval from injury to surgery remains controversial. Timely intervention could block the pathophysiological process and relieve nerve swelling and ischemia, possibly recovering the VA. Early intervention (within 3 days or even 7 days) with ETOCD or/and corticosteroid therapy has been proposed, and is regarded to yield a good prognosis (16,35-38). The efficiency rate in patients treated within 3 days was significantly higher than those in patients treated later than 7 days (63.6% *vs.* 35.7%) (36). However, if surgery was delayed, the operation could be completed for patients with NLP within 2 weeks and for patients with residual eyesight within 1 month, based on our experiences. Our study found that 35.5% patients (136/383) with blindness and 71.9% patients (69/96) with residual eyesight improved following EOND plus corticosteroids. According to the current literature, delayed operation time will affect the surgical treatment effect of ton. However, due to the unknown

pathological and physiological mechanism of TON and many influencing factors, it is difficult to confirm this conclusion by randomized controlled trials.

Although the percentage of improvement was not high relative to that of other studies, the majority of patients underwent surgery and corticosteroid therapy within 7 days or less. In addition to the surgical timing, the degree of optic nerve damage may vary, even if the patients all present with the same degree of blindness (8,9).

Compared with surgical timing, the baseline VA is a more important factor affecting prognosis. Patients with residual eyesight have more surviving RGCs and less functional loss of the optic nerve, which indicates greater potential for recovery after medical intervention (39,40).

Satisfactory postoperative results could be obtained in patients with residual eyesight before surgery (41). In our study, the improvement rate of patients with residual eyesight was significantly better than that of patients with blindness, even though the surgery on the former could be delayed until 1 month from onset. Only 136 patients (35.5%) with blindness improved after EOND, which is similar to the results of other investigations reporting improvement rates around 10–30%, but not as high as the 46.9% reported in another study (34,42-44).

Intraoperative CSF leakage is common EOND surgery, especially in patients with anterior skull fracture. Fully exposing the fistula, covering the mucosa, and filling the area with a collagen sponge, followed by patient confinement to bed for 7–10 days after surgery, can successfully repair CSF leakage. Except for the skull fractures, iatrogenic insult was another reason for CSF leakage, with a reported prevalence of 1.2%, which is higher than the 0.13% generally reported for endoscopic sinus surgery (45,46). For the patients with history of cerebrospinal fluid rhinorrhea before operation and serious fracture of anterior skull base on CT scans, it is necessary to operate carefully and avoid removing the displaced fracture bones.

Another rare but most serious complication is hemorrhage caused by CCF and traumatic aneurysm. Bleeding often occurs when the bone fragments are removed from the medial wall of the sphenoid sinus. In the present study, the only measure taken immediately was to inject the sinus with tela iodoformum, followed by DSA examination and interventional therapy. All patients recovered after embolization and were discharged without complications. In some cases, in the early stage after injury, no classic symptoms were evident, but if severe fractures or displacement of the medial wall of the sphenoid sinus, expanded superior ophthalmic vein, or broadened cavernous sinus existed, computed tomography angiography (CTA) or DSA examination was required to rule out CCF (47). If there were severe fractures in the area around the optic canal that were associated with traumatic subarachnoid hemorrhage, CTA was required to exclude traumatic aneurysm (48). Serious sphenoid sinus fracturs and subarachnoid hemorrhage on CT scans must be paid enough attentions and CTA or DSA need to be adopted to exclude the possibility of vascular injury.

Based on the findings of the present study, once diagnosed with TON, even with no definite fracture of the optic canal on HRCT scan, EOND surgery should be performed as soon as possible. However, if surgery cannot be undertaken within 7 days, EOND could still be used as a safe and effective therapeutic approach to improve VA in patients with NLP within 2 weeks and those with residual eyesight within 1 month. Wider decompression, including the superior wall of the optic canal, should be achieved whenever possible, but surgeons must be skilled in endoscopic surgery techniques to avoid complications. The superiority of wider decompression needs to be further demonstrated in large-sample, controlled, prospective studies.

Conclusions

Preoperative early surgical decompression plus steroid therapy for TON is regarded as an effective protocol, in which a surgical interval time of 7 days and basal VA are key factors influencing prognosis. However, delayed operation plus a megadose of steroid could still be regarded as an effective remedial measure within 2 weeks for patients with NLP and within 1 month for patients with residual eyesight.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The present study was approved by the ethical committee of our hospital, and informed consent was obtained from each participant. All procedures performed in this study involving human participants were in accordance with the Declaration of Helsinki (as revised in 2013).

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