The outcome of surgical and non-surgical treatments for traumatic optic neuropathy: a comparative study of 685 cases

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Background: The choice and efficacy of surgical or/and surgical treatments for traumatic optic neuropathy (TON) remained controversial by now. This study aims to present the outcomes of surgical and nonsurgical treatments for TON in our center.

Methods: A total of 685 consecutive patients were retrospectively included in the study. And divided into surgical and non-surgical groups. All cases were treated with corticosteroids for 3 days after admission. Endoscopic optic decompression was applied to 479 patients of surgical group; The other 206 patients of nonsurgical were administered with corticosteroids alone. The visual outcomes before and after treatment were compared with Wilcoxon rank and tests. The improvement rate between two groups were compared with chi-square test.

Results: The visual acuity (VA) after treatment was significantly better than that before treatment (P=0.000). Overall VA improvement rate in the surgical group was better than that in non-surgical group (42.8% *vs.* 35.4%) with no significant difference (P=0.072). The VA improvement rate was significant greater in the surgical group than that in the non-surgical group in the patients with NLP before treatment (P=0.028). The VA improvement rate was better in the surgical group than that in the non-surgical group (71.9% *vs.* 57.8%) but with no significant difference. The final overall VA was 0.1 or better in 43 cases; 104 cases were able to count fingers; hand motion (HM) became perceivable in 132 cases; light perception (LP) was achieved in 53 cases; and no light perception (NLP) remained in 353 cases.

Conclusions: Endoscopic optic nerve decompression (EOND) combined with corticosteroids or corticosteroids alone could reach the improvement for patients with TON. The EOND combined with corticosteroids could achieve better VA improvement in patients with NLP.

Keywords: Traumatic optic neuropathy (TON); corticosteroids; endoscopic optic nerve decompression (EOND); follow-up

Submitted Mar 21, 2022. Accepted for publication May 10, 2022.
doi: 10.21037/atm-22-1836
View this article at: https://dx.doi.org/10.21037/atm-22-1836

Introduction

Traumatic optic neuropathy (TON), the most common reason for visual loss after blunt head trauma, has an incidence of about 2.5–10% following blunt head trauma (1-3). According to the injury mechanism of the optic nerve, can TON be classified as either direct or indirect TON. Direct TON is caused by avulsion or impingement due to mechanical stress applied directly to the nerve by a variety of causes, such as penetrating foreign body and displacement of optic canal fracture. Indirect TON is caused by the shearing force transmitted from trauma, resulting in the injury to the optic nerve or pia meningeal vessels. Typical locations of such trauma are the forehead, superciliary arch, and temporal regions (4,5). When the optic nerve is affected by an external force, the direct shear force transmits to the optic nerve and the vessels, then the resulting optic nerve ischemia can aggravate optic nerve edema, especially in the optic nerve canal (6).

To date, no consistent benefits from the interventions of corticosteroids, optic nerve decompression, and spontaneous improvement have been demonstrated, and no consensus has been reached regarding the preferred treatment for TON. With the emergence of corticosteroids and optic nerve decompression surgery, more and more researchers are expressing preference for surgery or/and corticosteroid therapy, so as to achieve internal and external decompression after optic nerve injury and minimize the pathophysiological response after injury (7,8). However, the superiority and indications of the choice for TON patients with different post-traumatic eyesight remained controversial. Due to the inconsistency of the severity of injury, interval before surgery, dosage of steroids, and surgical techniques, the prognosis of TON varies widely.

Based on the individual conditions of cases presenting at the Department of Neurosurgery, Beijing Tongren Hospital for treatment after having initially visited other hospitals, the interventions had to start beyond 1 week after trauma for most participants. Here, we retrospectively reviewed 685 consecutive patients with TON and summarized the efficacy of different methods. The results will provide some valuable references in treating TON cases with delayed intervention more than 1 week after trauma, especially the comparative results of different therapy for different patients. We present the following article in accordance with the STROBE reporting checklist (available at https://atm.amegroups.com/article/view/10.21037/atm-22-1836/rc).

Methods

From September 2010 to August 2017, a total of 685 cases were diagnosed with TON and treated at the Department of Neurosurgery, Beijing Tongren Hospital.

All cases presented with visual loss with and pupillary afferent disorder in the involved eye due to craniofacial trauma and examined by an ophthalmologist firstly to eliminate injury of the eyeball and fundus. Then, the fractures of orbit and optic canal were evaluated by high resolution computed tomography (HRCT) scan with 1.0 mm section through the optic canal.

All cases were administered with methylprednisolone at a dosage of 1,000 mg intravenously for 3 days after admission to our department. If visual acuity (VA) did not improve to 6/60 after steroids treatment, endoscopic optic nerve decompression (EOND) was suggested and it is ultimately up to the patient' decision whether to undergo surgical treatment. Oral vasodilators, mecobalamin and hyperbaric oxygen, were performed for 2 weeks after discharge. Patients were divided into two groups according to the treatment regimen: surgical group (steroids plus surgery) and non-surgical groups (steroids alone). The overall improvement of VA was compared after treatment and the improvement rates were compared between two groups for the patients with NLP and residual eyesight. This study was approved by the ethics committee of our hospital (No. TRECKY2020-055), and informed consent was provided by each participant. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

Surgical procedure

The EOND was performed under general anesthesia and controlled hypertension. The nasal cavity was converged with cotton strips soaked with 0.1% adrenaline and 1% lidocaine to reduce bleeding of the nasal mucosa. A routine endoscopic ethmoidectomy and sphenoidotomy were performed. After exposure and confirmation of the optical canal, the medial, inferior, or/and superior walls of optic canals were grinded carefully and removed by diamond burr and removed by a micro exfoliator. The range of decompression was involved the entire length of the optical canal including the cranial and orbital foramens and orbital apex. The optic nerve sheath was opened if intrasheath hematoma or severe swelling of optic nerve were observed. Methylprednisolone, vasodilators, and neurotropic drugs were administered for 1 week postoperatively.

Visual evaluation

The criteria to define improvement in VA includes: (I) an improvement of 1 line or more on the Snellen visual chart; (II) eyesight increased from no light perception (NLP) to light perception (LP) or better; (III) eyesight improved from LP to hand motion (HM) or better; (IV) eyesight improved from HM to fingers counting (FC) or better.

Table 1 Clinical manifestations and examination results of patients with TON

TON	Cases (%)
Gender	
Male	621 (90.6)
Female	64 (9.4)
Mechanism	
Motor accident	484 (70.6)
Falling accident	128 (18.7)
Crushing blow	52 (7.6)
Others	21 (3.1)
Eyesight	
NLP	525 (76.6)
LP	47 (6.9)
Hand movement	67 (9.8)
Fingers couting	46 (6.7)
Fundoscopy	
Optic nerve papilla abnormality	57 (8.3)
Normal optic papilla	618 (91.7)
HRCT	
Fracture of optic canal	594 (86.7)
No fracture of optic canal	91 (13.3)
Groups	
Surgical group	479 (69.9)
Non-surgical group	206 (30.1)

TON, traumatic optic neuropathy; NLP, no light perception; LP, light perception; HRCT, high resolution computed tomography.

The VA was followed up at 1 week, 1 month, and 3 months after discharge by an ophthalmologist. The VA at discharge of 57 patients (8.3%) and that of 64 patients (9.3%) at 1 month after discharge were chosen as the final results because of the failure to follow up.

Statistical analysis

All statistical analysis were conducted using SPSS 22.0 (IBM Corp., Armonk, NY, USA). The chi-square test was applied to evaluate difference of improvement rate between the surgical and non-surgical groups. Wilcoxon rank and tests were employed to evaluate the VA before and after interventions. Statistical significance was considered at P<0.05.

Results

The baseline characteristics of all cases are described in *Table 1*. Among the 685 cases with a diagnosis of TON, 621 were male and 64 were female. Their ages ranged from 5 to 67 years (average 32.3±14.9 years). The most common causes of TON in this study were traffic accidents (484 cases), followed by fall accidents (128 cases), and crushing blows (52 cases). Of the 685 patients, 525 presented with NLP, 47 with LP, 67 with HM, and 46 with FC upon admission. The time interval from injury to surgery ranged from 7 to 31 days (average interval 11.8±4.92 days). A total of 479 cases underwent surgery within 1 month and 206 cases received non-surgical treatment.

Among the 685 cases, the final VA remained NLP in 353 cases, LP in 53 cases, HM 132 cases, FC in 104 cases, and 6/60 or better in 43 cases during follow-up periods from 1 week to 2 years after treatment (average 3.87±1.04 months). The post-treatment VA was significantly better than pre-treatment VA (P<0.01). The pre- and post-treatment VA are described in *Table 2*.

Of the 206 patients who were treated non-surgically, 73 cases (35.4%) gained improvement. Of the 479 patients who were treated with EOND, 205 cases (42.8%) gained improvement after operation. Although the improvement rate in surgical group was higher than non-surgical group, the difference was not significant (P=0.072) (*Table 3*).

A total of 136 cases (35.5%) improved after operation among 383 cases with NLP in the surgical group and 36 cases (27.4%) improved among 142 cases with NLP in the non-surgical group. The improvement rate in the surgical group was significantly higher than that of the non-surgical group among NLP cases (P=0.028) (*Table 4*).

Meanwhile, 69 cases (71.9%) gained improvement after surgery among 96 cases with residual eyesight in the surgical group and 37 cases (57.8%) improved among 64 cases in the non-surgical group. The improvement rate with surgical treatment was higher than that of the non-surgical treatment group in NLP cases, but the difference was not significant (P=0.065) (*Table 5*).

Discussion

After blunt head injury especially in crania-facial trauma, TON is the most common reason for the decline of

Table 2 Comparison of eyesight before and after treatment in cases with TON

Group	NLP (n)	LP (n)	HM (n)	FC (n)	VA ≥0.1 (n)	Total (n)
Pre-treatment	525	47	67	46	0	685
Post-treatment	353	53	132	104	43	685

Z=–14.736, P=0.000. Significant difference between eyesight before treatment and eyesight after treatment in patients with TON (P<0.01). VA increased significantly after treatment. Wilcoxon rank and tests were used for the comparison of VA between two groups. TON, traumatic optic neuropathy; NLP, no light perception; LP, light perception; HM, hand motion; FC, fingers counting; VA, visual acuity.

Table 3 Comparison of the VA improvement rate with different treatment for TON

Group	Improvement	No improvement	VA improvement rate	P value
Surgical	205	274	42.8	0.072
Non-surgical	73	133	35.4	

Comparison of VA improvement rate with different treatment for TON. VA improvement rate in the surgical group was better than that in the non-surgical group but with no significant difference. χ^2=3.237, P=0.072. The χ^2-test was applied to compare VA improvement rate between the two groups. VA, visual acuity; TON, traumatic optic neuropathy.

Table 4 Comparison of the VA improvement rate with different treatment for TON with NLP

Group	Improvement	No improvement	VA improvement rate	P value
Surgery	136	247	35.5	0.028
Non-surgical	36	106	25.4	

Comparison of VA improvement rate with different treatment for TON with NLP. VA improved significantly higher in the surgical group than that in the non-surgical group. χ^2=4.852, P=0.028. The χ^2-test was applied to compare VA improvement rate between the two groups. VA, visual acuity; TON, traumatic optic neuropathy; NLP, no light perception.

Table 5 Comparison of the VA improvement rate with different treatment for TON with residual eyesight

Group	Improvement	No improvement	VA improvement rate	P value
Surgical	69	27	71.9	0.065
Non-surgical	37	27	57.8	

Comparison of VA improvement rate with different treatment for TON with residual eyesight. VA improvement rate was higher in the surgical group but with no significant difference compared with non-surgical group. χ^2=3.396, P=0.065. The χ^2-test was applied to compare VA improvement rate between the two groups. VA, visual acuity; TON, traumatic optic neuropathy.

eyesight. In this study, TON mainly occurred in young men (621 cases, 90.6%). There were 484 cases (70.6%) of injury by traffic accident and 128 cases (18.7%) of injury by falling. The characteristics of this series are consistent with those of previous studies (7,9); however, 525 eyes (76.6%) were completely blind after the injury, which is higher than the 40–60% reported in the literature. The reason may be related to inadequate traffic safety precautions, especially the head safety protection measures, taken by motorcycle and electric vehicle drivers (9,10). The therapeutic results suggested that EOND combined with corticosteroid therapy or corticosteroid therapy alone were both beneficial for improving the VA of TON, but EOND plus corticosteroid therapy was more effective than that of corticosteroid therapy alone, especially in the cases with NLP on admission.

The shearing forces transmitted from cranial-facial trauma damage the optic nerve and nutrient vessels, followed by the formation of compartment syndrome in the confined optic canal, especially with the displacement of fractures. The further compression could exacerbate ischemia and injury to axons, which leads to poor prognosis.

Based on the injury mechanism above, the internal decompression with steroids therapy, or the external decompression with EOND, or a combination of both have been advocated for the treatment of TON.

The treatment of TON with megadose of steroids is mainly to alleviate the microcirculation disturbance and edema caused by optic nerve injury, to block the progression of secondary insult to the optic nerve. Seiff found that VA improved in 13 of 21 patients (62%) treated with dexamethasone and in 5 of 15 untreated patients (33%), but without significant difference (11). Spoor reported that VA improved in 12 of 22 (54.5%) patients treated with dexamethasone or methylprednisolone (12). Although many studies have reported that corticosteroid therapy alone could achieve a 50% improvement rate, most of them are small sample size, retrospective, and non-randomized studies, so there is the possibility of selection bias (13,14). So far, no significant difference of VA was revealed in the double-masked, placebo-controlled, randomized trial of treatments with high-dose intravenous steroids and placebo (1.11±1.14 *vs.* 1.78±1.23). Although VA improved more in the treatment group (68.8% *vs.* 53.3%), the difference was not statistically significant.

High-dose corticosteroid therapy (5.4 mg/kg/h for 24 or 48 hours) had always been regarded the only treatment for TON, attempting to alleviate post-traumatic swelling of the optic nerve and improve eyesight. However, it has been abandoned due to the possibility of a serious complications, such as acute psychosis, acute pancreatitis, and gastrointestinal bleeding, even in the treatment of spinal cord injury and brain injury. As the efficiency of intravenous methylprednisolone injection at a dose of 1,000 mg/d for 3 days has been evidenced in the treatment of optic neuritis, it was adopted in our center, with no apparent side effects (15).

In our study, overall VA improved in 73 of 206 cases (35.4%) treated with corticosteroid alone, but VA only improved in 36 of 106 cases (25.4%) with NLP after trauma, which was significantly worse than those with the treatment of EOND plus corticosteroid therapy. According to the cases with residual eyesight, the EOND plus corticosteroid did not obtain a significantly high improvement rate compared to those who received corticosteroid therapy alone, but the levels of improvement failed to be evaluated in this series.

There are many inconsistencies in the current studies, such as sample size, selection of cases, treatment dose, treatment time, and judgment criteria. There is no convincing evidence that corticosteroids help to promote the recovery of TON over conservative management; however, when TON is diagnosed, high-dose corticosteroid therapy was applied for the initial intervention in most studies. A meta-analysis of 244 patients with TON demonstrated that medical therapy with corticosteroids and/or optic nerve decompression experienced better improvement than that of no treatment but observation alone (16). However, the subsequent International Optic Nerve Trauma Study (IONTS), including 133 patients with TON, found no significant difference between corticosteroid treatment, surgical decompression, and observation alone (17).

In theory, optic canal decompression is beneficial to relieve constriction of the osseous structure to the optic nerve, especially in cases of optic nerve swelling due to edema, hematoma, or swelling of the nerve or nerve sheath. The VA could improve due to the amelioration of the secondary injuries such as inflammatory reaction, and degeneration, and regeneration of retinal ganglion cells (RGCs) after TON (18,19).

To date, surgical decompression with or without corticosteroids has been advocated by most authors. The treatment protocols have largely depended on the preferred practice of the individual clinicians or institute rather than from robust clinical evidence (20).

With the development of instruments and endoscopic techniques, EOND has become the first choice for the surgical decompression if with meticulous manipulation. Through the efficacy of surgical treatment on TON, EOND combined with corticosteroids, is generally considered a valid strategy to improve visual outcomes (8).

It has been reported that combined therapies of EOND and corticosteroids provide VA improvement rates ranging from 9.5% to 82.4% in adults and 45.8% to 80.5% in children (21). The VA improvement rate of combined therapies in our study was 42.8% (205/479 cases), which is similar to the results mentioned above. The results in these series vary considerably, but it is difficult to interpret because of the inherent bias and inconsistencies of the therapy protocols. Though no consensus has been reached, several factors are thought to be related to the prognosis, such as surgical timing, initial VA, and fractures of the optic canal (14,22-24).

Early intervention with EOND or corticosteroids or combination of them within 7 or even 3 days after trauma is considered a good prognostic factor (8,22-25).

However, if the treatment is delayed due to objective conditions, the medical intervention should be applied to the cases with NLP within 2 weeks, and within 1 month for cases with residual eyesight. This case series showed 172 cases (172/525, 33.7%) with blindness and 106 cases (106/160, 66.3%) with residual eyesight who gained improvement from medical intervention. Intervention within 2 weeks is extremely crucial to improve the VA after trauma, especially for the cases with NLP (26).

In addition to the surgical timing, the post-traumatic eyesight is another important prognostic factor. The initial eyesight is on behalf of the extent of optic nerve damage. Better initial VA indicates that more surviving RCG cells remained after trauma. The patients with residual VA were more likely to improve after intervention compared to those with NLP. Just as the results in our previous series, the prognosis in the cases with residual VA was significantly better that with NLP (23,24,27,28).

It is plausible that the degree of craniofacial fracture is related to the severity of stress, even to the degree of optic nerve injury. Zygomatic, frontal, nasal, and orbital fractures were identified to relate to the occurrence with TON, especially with combined fractures of them. Optic canal fracture is a part of craniofacial fractures, and its injury mechanism is complex and unclear. To clarify the relationship between the severity of craniofacial fractures and the degree of optic nerve injury or prognosis, many researchers have established scoring systems based craniofacial fractures on the computed tomography (CT) findings. However, these studies have mainly been small sample and non-randomized trials, and the validity needs further investigation (29-32).

Complete decompression of the optic nerve is the most important therapeutic goal. It has been shown that optic nerve sheath fenestration (ONSF) could effectively relieve the papilledema and visual loss resulting from the idiopathic intracranial hypertension and other nontraumatic optic neuropathy. According to these results, some authors advocated incision or penetration of the optic nerve sheath on the basis of osseous decompression of optic canal (33,34).

However, the pathophysiological mechanisms of these 2 diseases are completely different, and the application of ONSF in TON is unwarranted. Moreover, the therapeutic efficacy remained unclear in current literatures (25,35). In our experience, incision of the optic nerve sheath is only performed in the cases with intrathecal hemorrhage of the optic nerve and severe swelling of the optic nerve. Although the decompression enlarges after incision, the risk of cerebrospinal fluid (CSF) leakage, injuries to the ophthalmic artery, or the pial vessels and optic nerve fascicles would increase correspondingly. So, incision of the sheath was performed only for 42 cases, even though no above-mentioned complications appeared. Due to better exposure and view of the optic canal and surrounding structures, the incidence of surgical complications was significantly lower than that of traditional craniotomy. The most common complication of EOND is intraoperative CSF leakage with an incidence of 1.2%, which occurred 0.13% in endoscopic sinus surgery (ESS) (36,37).

On the one hand, in the cases of severe anterior skull base fractures, the fracture pieces penetrating the dura mater were removed and CSF leakage occurred; on the other hand, when grinding off the optic nerve wall, especially on the upper wall, it is easy to damage the dura of the anterior skull base, resulting in CSF leakage. In addition, in the cranial orifice of the optic nerve, the optic nerve sheath becomes thinner and more adhered to the optic canal, which is easy to be damaged and cause CSF leakage during the decompression course. Repairing with the mucosa after complete exposure of the fistula, compressing with collagen sponge, followed by braking on the bed strictly for 7–10 days after surgery can successfully repair CSF leakage. For severe CSF rhinorrhea, a septal mucosal flap can be used to repair the leakage.

Intraoperative hemorrhage is another rare but most serious complication of EOND, resulting from traumatic carotico-cavernous fistulae (CCF) or traumatic aneurysm. To avoid the occurrence of this situation, computed tomography angiography (CTA) or digital subtraction angiography (DSA) examination should be performed on cases with multiple or displaced fractures of the medial wall of sphenoid sinus, or enlarged superior ophthalmic vein, or broadened cavernous sinus on CT findings. Severe fractures surrounding the optic canal and marked subarachnoid hemorrhage on initial CT findings are strongly linked to the possibility of traumatic aneurysm; CTA should be required to clarify the diagnosis. Vascular complications should be emphasized and screened preoperatively if related signs show on CT images, to reduce the occurrence of intraoperative bleeding. If CCF or traumatic aneurysm is diagnosed, neuro-endovascular intervention therapy is usually effective (38).

Conclusions

The combination of EOND and corticosteroids, or corticosteroids alone are both effective in the treatment of TON, but EOND could increase the improvement rate, especially in patients with NLP. However, this study is not a randomized controlled trial and the bias is inevitable. Therefore, the study only provides our experience in TON treatment, and more rigorous results need to be studied in future randomized controlled trials.

Acknowledgments

Funding: The present study was supported by the Beijing Hospitals Authority's Ascent Plan (No. DFL20190201).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist Available at https://atm.amegroups.com/article/view/10.21037/atm-22-1836/rc

Data Sharing Statement: Available at https://atm.amegroups.com/article/view/10.21037/atm-22-1836/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://atm.amegroups.com/article/view/10.21037/atm-22-1836/coif). The authors have no conflicts of interest to declare.

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. This study was approved by the ethics committee of Beijing Tongren Hospital (No. TRECKY2020-055), and informed consent was provided by each participant. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013).

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(English Language Editor: J. Jones)

Cite this article as: Wei W, Zhao SF, Li Y, Zhang JL, Wu JP, Liu HC, Sun S, Song GD, Ma JM, Kang J. The outcome of surgical and non-surgical treatments for traumatic optic neuropathy: a comparative study of 685 cases. Ann Transl Med 2022;10(10):542. doi: 10.21037/atm-22-1836