Endonasal Endoscopic Optic Canal Decompression for Nontraumatic Optic Neuropathy: Long-Term Visual Outcomes in 36 Patients

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Background: The management of compressive optic neuropathy (CON) arising from nontraumatic compression of the optic nerve within the optic canal (OC) remains a topic of controversy. In this study, our aim was to assess the effectiveness and safety of endonasal endoscopic optic nerve decompression (EEOND). In addition, we conducted an analysis of prognostic factors that could potentially influence visual outcomes.

Methods: This retrospective cohort study was conducted between January 2015 and December 2021, involving adult patients (age $>$ 18) diagnosed with CON and treated with EEOND at our specialized skull base expert center. The study evaluated the impact of surgery on visual acuity (VA), mean deficit (MD), and foveal threshold (FT) of the visual field (VF). These parameters were assessed preoperatively and at 3- and 12-month postoperative follow-ups. The relationship between clinical variables and the differences in postoperative to preoperative VA, MD, and FT of the visual field was analyzed through univariate and multivariate approaches.

Results: Thirty-six patients (38 eyes) were included, with a mean age of 52 (±12) years, and a female predominance (78%). The mean ophthalmologic follow-up duration was 38 (±32) months. At the 12-month follow-up, 39% of the patients exhibited a VA improvement of $\geq$0.2 LogMAR. Partial VF improvement (MD improvement $\geq$25%) was observed in 55% of the patients, whereas 19% experienced complete recovery. In multivariate analysis, the presence of a type 4 OC was identified as the sole negative prognostic factor for visual improvement (VA and VF) at 12 months. Six patients (17%) encountered minor surgical complications, all of which were managed conservatively and had no impact on visual outcomes.

Conclusions: Our study demonstrates that EEOND is a safe and effective procedure, even in cases of severe and long-lasting CON caused by nontraumatic compression of the optic nerve at the level of the OC.

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The surgical management of compressive optic neuropathy (CON) resulting from nontraumatic compression of the optic nerve at the optic canal level poses significant challenges and remains a topic of controversy. The decision to opt for surgical decompression is influenced by topographical considerations related to the anatomy of the optic canal (OC). Approaches such as pterional craniotomy and lateral orbitotomy offer access to the lateral wall and roof of the OC, whereas the endonasal endoscopic transsphenoidal approach provides excellent exposure of the OC's inferior and medial walls.[1–5] Although there have been limited reports on the effectiveness of endonasal endoscopic optic nerve decompression (EEOND) for optic neuropathy, these studies have been conducted in small series with varying indications and follow-up periods, yielding promising results.[1–12]

Our study aimed to evaluate the effectiveness and safety of EEOND in adults suffering from nontraumatic CON caused by optic nerve compression at the level of the optic canal. To our knowledge, this study represents the most extensive series published to date on this specific topic. The primary objective of our research was to assess short- and long-term visual improvements after EEOND. In addition, we conducted an analysis of preoperative factors that could potentially influence visual outcomes.

METHODS

Study Population

We conducted a retrospective cohort study spanning from January 2015 to December 2021. This study included all consecutive patients treated with EEOND for CON resulting from nontraumatic compression at the optic canal level, in our Skull Base Surgery unit (Department of Neurosurgery B, Neurological Hospital P Wertheimer, Lyon University Hospital, France).

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Patients were managed from a multidisciplinary team comprising neurosurgeons, neuro-ophthalmologists, ENT surgeons, and maxillofacial surgeons, and radiotherapists, neuro-oncologists, and neuroradiologists. For each patient, decision for EEOND was discussed during a monthly multidisciplinary meeting. The decision to perform EEOND for each patient was made collectively during our monthly multidisciplinary meetings.

For our research, data were meticulously gathered from preoperative and postoperative ophthalmologic examinations, operative reports, and hospital records. Exclusion criteria included age<18, traumatic CON, and dysthyroid CON.

Ophthalmologic Evaluation

The ophthalmologic assessment was conducted by neuro-ophthalmologists before the surgery and at 3 and 12 months, postoperatively. This evaluation encompassed a detailed analysis of papillary morphology (papillary atrophy or papillary edema), the presence of a relative afferent pupillary defect (RAPD), the best-corrected far visual acuity (VA) (Monoyer's scale converted to logarithm of minimum angle of resolution [LogMAR]), the retinal nerve fiber layer (RNFL) papillary OCT measurement (Heidelberg Engineering OCT Spectralis, Franklin, TN), and the visual field (VF) description: type of visual field impairment, mean deficit (MD), and foveal threshold (FT) (Metrovision MonPack One, Pérenchies, France). In cases where patients had bilateral CON, each eye was analyzed individually. The study meticulously tracked the changes in the ophthalmologic examination findings before and after surgery for each eye.

The preoperative VF was categorized as follows: normal, concentric deficit, altitudinal deficit, temporal hemianopsia, central or caeco-central scotoma, or global deficit. Currently, there is no consensus on the cutoffs used to define partial or complete improvement in MD and FT when assessing VF improvement after CON treatment. In our standard practice, we have established specific cutoff values for defining postoperative VF improvement: complete recovery was defined as the VF returning to normal, partial recovery was determined if MD improved by ≥25% and FT improved by ≥10%, and no recovery was indicated if MD and FT improved by <25% and <10%, respectively.

Anatomy of the Optic Canal

Preoperative OC conformation was assessed on the preoperative CT scans, considering its relationship with the sphenoid sinus wall based on the DeLano classification[13] as follows:

- Type 1 Adjacent to sphenoidal sinus;
- Type 2 Indentation on sphenoidal sinus;
- Type 3 Optic nerve traversing sphenoidal sinus;
- Type 4 Adjacent to sphenoidal and posterior ethmoidal air cells.

The extent of the OC decompression was evaluated on an early postoperative CT scan and/or MRI.

Surgical Technique

Our surgical technique has been previously detailed.[2] In brief, the procedure typically commenced with a middle and superior turbinectomy, ethmoidectomy, and sphenoidotomy on the side corresponding to the affected optic nerve. The medial wall of the orbital apex (lamina papyracea) was then removed, exposing the anterior end of the optic canal. The extent of the orbital apex opening depended on the degree of optic nerve compression within the orbit. OC decompression was conducted using a high-speed diamond drill (or an ultrasonic bone cutter) with continuous irrigation to minimize heat transfer to the optic nerve. A spatula was used to delicately remove the thin remaining bony layer, progressing from the anterior to the posterior direction. The posterior extension of the OC opening reached up to the tuberculum sellae. It is noteworthy that opening the optic nerve sheath carries substantial risks, including direct optic nerve damage, vascular injury (hemorrhagic and/or ischemic) of the ophthalmic artery, and postoperative cerebrospinal fluid leakage. Consequently, this step was omitted in our cohort. If the tumor was sufficiently exposed, a biopsy or partial resection was performed based on the surgical goals.

After the procedure, an early control CT scan was conducted to confirm the adequacy of decompression and to rule out any complications before patients were discharged within 2–3 days.

Mutlimodal Treatment of Compressive Optic Neuropathy

The management of CON associated with skull base tumors presents a significant challenge and necessitates a multimodal approach. All treatment decisions were meticulously crafted during our multidisciplinary meetings. Given its minimally invasive nature, we routinely explored the potential benefits of EEOND in patients with CON. EEOND was considered appropriate when optic canal compression was limited and not caused by severe osseous thickening, such as in cases of fibrous dysplasia or certain spheno-orbital meningiomas, where extensive drilling could potentially harm the optic nerve.

In addition to EEOND, some patients underwent transcranial surgery and/or received adjuvant radiotherapy. Additional transcranial surgery was recommended if EEOND yielded insufficient results or in cases of CON recurrence, tumor progression, or when reducing tumor volume before radiotherapy was deemed necessary. Radiotherapy was administered in situations involving new CON progression and/or tumor growth after surgery.

Statistical Analysis

The difference between postoperative (at the times indicated in the main text) and preoperative VA, MD, FT, and RNFL was calculated for each patient. For univariate analyses, VA, MD, or FT between groups were compared with Student *t*-test. Correlation between VA, MD, and FT and continuous variables were calculated by mean of Spearman rank correlation coefficient. For multivariate analyses, covariates that resulted in significantly associated visual outcome in the univariate analyses were fitted to a linear model including VA, MD, or FT as outcome measure and dependent variable. Subsequently, analysis of variance for each of the models was computed and reported in Figure 1. All statistical tests performed were two-tailed and the significance threshold was set at 0.05. All statistical analyses were performed in R 4.1.1.

Ethical Considerations

All procedures conducted in this study adhered to the ethical standards outlined by institutional and national research committees, following the principles of the 1964 Helsinki Declaration and its subsequent amendments. The study design was approved by the review board of the French National College of Neurosurgery (IRB00011687/College de Neurochirurgie IRB #1: 2023/06). Because of its purely observational nature, the review board waived the necessity for written informed consent from individual patients. This research did not receive specific funding from public, commercial, or not-for-profit sectors.

RESULTS

Patients' Characteristics

Over the 7-year study period, 36 patients underwent EEOND for nontraumatic CON at our skull base unit. The patients had a mean age of 52 (±12) years, and there was a predominance of females (78%). The mean VA measured on LogMar scale was 0.45 (SD 0.39). All patients presented with a visual field defect, with a mean MD of −9.65 (6.17). Further details regarding the patients' characteristics can be found in Tables 1 and 2.

Treatment of Compressive Optic Neuropathy

During the study period, 22 left eyes and 16 right eyes underwent EEOND, with 2 patients undergoing bilateral

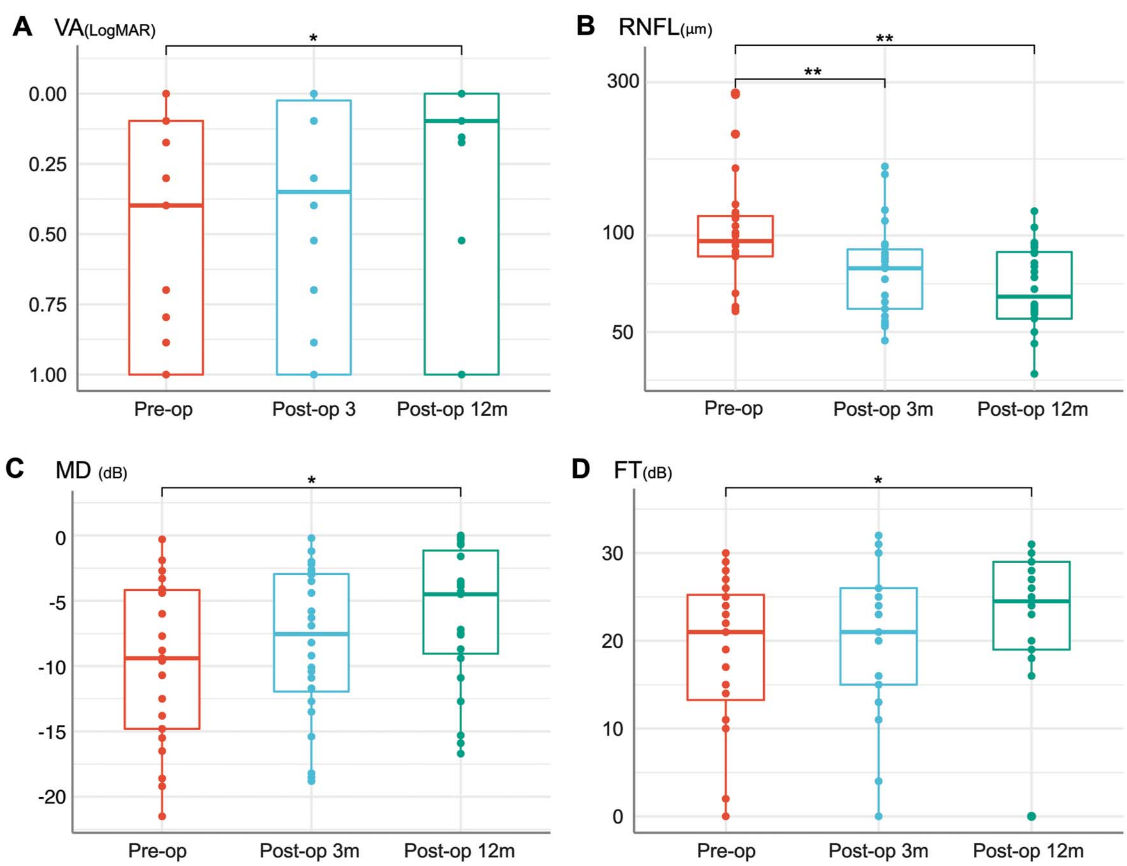

FIG. 1. Evolution of ophthalmologic evaluation at presentation (pre-op), 3-month (post-op 3m), and 12-month (post-op 12m) follow-up. **A**. Evolution of visual acuity (VA) (LogMAR). Decreased LogMAR corresponds to VA improvement. **B**. Evolution of retinal nerve fiber layer (RNFL) (µm). **C**. Evolution of mean deficit (MD) (dB), corresponding to the overall value of the total amount of visual field loss, with normal values typically within 0 dB to −1.5 dB. **D**. Evolution of foveal threshold (FT) (dB), representing an estimation of central visual function, with a normal value at 31 dB. *$P < 0.05$; **$P < 0.001$.

EEOND. The mean time between the onset of CON and EEOND was 6 (±6) months. The average surgical duration was 116 minutes (±38). Among the patients, 6 (17%) experienced surgical complications, including 2 cases of epistaxis, 2 instances of new-onset ophthalmoplegia, 1 orbital hematoma, and 1 CSF rhinorrhea. All complications were managed conservatively, and none of the patients experienced worsening of VA or VF because of these complications.

Thirteen patients (36%) underwent additional transcranial surgery (transpterional and/or lateral orbitotomy) to remove intracranial or intraorbital tumor extensions, with a mean delay of 24 (±28) months. Among them, 7 of 13 were treated for spheno-orbital meningiomas, where EEOND and the transcranial approach were complementary because of the involvement of the OC and orbit. In addition, 55% of the patients received adjuvant radiotherapy, with an average delay of 17 (±14) months.

EEOND alone successfully treated CON in 36% of our patients, obviating the need for further treatment.

TABLE 1. Demographic, clinical, and anatomical characteristics of the patient at the time of presentation

	N (%)
Female sex	28 (78%)
Median age, (range)	52 (46; 62)
Pathology	
Spheno-orbital meningioma	15 (42%)
Optic nerve sheath meningioma	6 (17%)
Clinoidal meningioma	3 (8%)
Cavernous sinus meningioma	3 (8%)
Tuberculum sellae meningioma	2 (6%)
Fibrous dysplasia	1 (%)
Idiopathic optic neuropathy	1 (%)
Mucocela	1 (%)
Mucormycose	1 (%)
Nasal polyposis (Rendu-Osler)	1 (%)
Optic nerve neurinoma	1 (%)
Petro-clival meningioma	1 (%)
Anatomic type of optic canal*	
1	10 (28%)
2	14 (39%)
3	7 (19%)
4	5 (14%)
Aspect of papilla	
Papillary atrophy	19/33 (53%)
Papillary edema	9/35 (25%)
Type of visual field impairment	
No visual field impairment	2/34 (6%)
Concentric	7/34 (21%)
Altitudinal	7/34 (21%)
Temporal hemianopsia	3/34 (9%)
Caeco-central scotoma	8/34 (24%)
Global	6/34 (18%)

*According to Delano classification.[13]

Visual Outcomes

The mean ophthalmologic follow-up duration was 38 months (±32). Thirty-three patients (92%) had a 3-month follow-up, and 31 (86%) had a 12-month follow-up.

At the 3- and 12-month follow-ups, 18% and 39% of patients, respectively, exhibited a VA improvement of ≥0.2 LogMar. Three patients, all presenting with preoperative papillary atrophy, experienced VA worsening at the 3-month follow-up. By the 12-month follow-up, one patient maintained the same VA (5/10), one recovered his initial VA (8/10), and one was lost to follow-up. Overall, there was a significant improvement in VA 12 months after EEOND ($P = 0.021$) (Fig. 1).

At the 3-month and 12-month follow-ups, 63% and 74% of patients showed improvements in their VF, respectively. Specifically, 60% and 55% of patients experienced partial VF improvements at 3 and 12 months, whereas 3% and 19% fully recovered during the same periods. There was a significant enhancement in the global VF (MD) at 12 months ($P = 0.036$), and in the central VF (FT) ($P = 0.024$) (Fig. 1).

The number of patients with papillary atrophy increased from 58% in the preoperative examination to 74% at the 12-month follow-up, which was correlated with a statistically significant ($P < 0.01$) continuous decrease in RNFL thickness from 108 (±56) μm preoperatively to 69 (±21) μm at the 12-month follow-up.

Detailed visual outcomes are presented in Table 2 and Figure 1.

Prognostic Factors

Higher age, female sex, other cause of CON than meningioma, preoperative papillary atrophy, and Type 4 optic canal (Delano classification) were associated with worse visual outcome at 12 months.

In the multivariate analysis, Type 4 optic canal was identified as the sole negative prognostic factor for VA improvement at 12 months, whereas age showed an inverse correlation with foveal threshold improvement at the same period. Interestingly, the severity of visual impairment and the duration of symptoms were not identified as negative prognostic factors.

DISCUSSION

Surgical intervention for CON related to OC compression remains poorly described and contentious. This study sheds light on the long-term improvement in visual outcomes after EEOND for CON associated with nontraumatic compression of the optic nerve within the OC.

Many previous publications have examined mixed populations, incorporating cases of dysthyroid optic neuropathy. In this study, we deliberately excluded dysthyroid

TABLE 2. Visual status of the patients

	Pre-op n = 36	Post-op 3 mo n = 33	*P* 0–3 m	Post-op 12 mo n = 31	*P* 0–12 m
Visual acuity					
Mean (SD)	0.45 (0.39)	0.47 (0.40)	0.89	0.64 (0.42)	0.021
Improved (≥2/10)		6 (18%)		12 (39%)	
Unchanged		24 (73%)		18 (58%)	
Worsened		3 (9%)		1 (3%)	
Visual field					
MD (SD)	−9.65 (6.17)	−8.73 (5.8)	0.64	−6.64 (5.61)	0.036
Mean FT (SD)	18.68 (8.8)	18.46 (10.06)	0.51	22.3 (8.02)	0.024
Improvement					
Complete		1 (3%)		6 (19%)	
Partial		20 (60%)		17 (55%)	
None		12 (36%)		8 (26%)	
Ophthalmoplegia	2 (6%)	4 (12%)		4 (13%)	
RAPD	23/31(74%)	23/33 (70%)		15/31 (48%)	
Papillary morphology					
Normal	5/33 (15%)	—		6/31 (19%)	
Oedema	9/33 (27%)	—		2/31 (6%)	
Atrophy	19/33 (58%)	—		23/31 (74%)	
RNFL mean, μm (SD)	108 (56)	78 (29)	<0.01	69 (21)	<0.01

FT, foveolar threshold; MD, mean deficit; RAPD, relative afferent pupillary defect.

optic neuropathy, where the optic nerve is compressed at the orbital apex rather than within the OC. Our aim was to specifically evaluate the efficacy of EEOND in decompressing the optic nerve at the OC level.

Our findings affirm the effectiveness of this surgical approach, demonstrating significant and enduring improvements in VA for 39% of cases and in VF for 74% of cases at the 12-month follow-up. It is important to contextualize these results considering the initial severity of visual impairment, because 85% of our patients exhibited papillary impairment during the preoperative examination.

Furthermore, our study revealed that the severity and duration of preoperative visual impairment were not negative prognostic factors. Consequently, patients with severe impairment or longstanding CON should not be excluded from consideration for EEOND.

The primary negative prognostic factor for visual outcomes at the 12-month mark was the presence of a type 4 optic canal configuration. In alignment with findings by Delano et al,[13] this configuration was relatively rare in our series. Postoperative scans for these patients consistently showed incomplete decompression in the inferior proximal part of the optic canal, potentially explaining the diminished results. One plausible explanation is that in this configuration, the optic nerve may be partially obscured by a spheno-ethmoidal cell (Onodi cell). Surgeons must exercise extreme caution when opening this cell during surgery to avoid damaging not only the optic nerve, but also the internal carotid artery, which can be dehiscent in up to 11% and 34% of cases, respectively.[14] Therefore, identifying the posterior spheno-ethmoidal cell during preoperative planning is imperative to anticipate challenges during EEOND. Although statistically significant, our conclusions are tempered by the limited number of cases (only 5 patients) with diverse conditions, leaving some uncertainty.

Negative prognostic factors for visual improvement were observed exclusively in nonmeningioma conditions. Among them, we encountered a single case of fibrous dysplasia in a patient experiencing deteriorating vision. Given the relatively less substantial thickness of hyperostosis at the inferomedial part of the optic canal and the absence of viable alternative treatments, we opted for EEOND. However, the surgery, hindered by technical challenges, did not result in any improvement for the patient. Likewise, it is crucial to emphasize that in our early experiences, patients with significant hyperostosis on the medial and inferior part of the optic canal, who underwent EEOND, did not demonstrate improvement; in certain cases, their condition even deteriorated. Consequently, we have ceased using EEOND for such cases and do not recommend this procedure for individuals with substantial hyperostosis in these areas of the OC.

Optic nerve sheath meningioma, although controversial in surgical treatment, did not exhibit similar negative outcomes. Among the 6 patients in our series treated for this condition, 5 were followed up for ≥12 months: 2 showed VA improvement (0.4 and 0.2 LogMar), and 3 had unchanged VA; all but one experienced partial or complete VF improvement. Two patients who did not receive adjuvant radiotherapy demonstrated VA and VF improvement at the 12-month mark. These results provide encouraging evidence for considering EEOND in the treatment of optic nerve sheath meningioma. However, it is crucial to emphasize that EEOND is only indicated when the OC and orbital apex are involved.

In addition, our study underscored the safety of EEOND, with only 6 patients (17%) encountering minor surgical complications. All of these complications were managed conservatively and had no negative impact on the visual status of the patients.

Our study has certain limitations. Its retrospective design introduces potential methodologic biases, although these were mitigated by the high-quality, prospectively collected data by an experienced neuro-ophthalmologic team. In addition, half of the cohort received radiotherapy, which could have contributed to visual improvement. However, it is crucial to note that radiotherapy was indicated only in cases of incomplete recovery after EEOND. Given the mean time interval of 17 months between surgery and radiotherapy, and the delayed effects of radiotherapy, any overlapping impact on the evaluation of surgical outcomes at the 3- and 12-month follow-ups is considered negligible. Similarly, the substantial delay (mean 24 months) before additional transcranial surgery reduces the risk of confounding results in patients who underwent both surgeries (only 2 patients received a second surgery within 6 months after EEOND).

Although our study cannot definitively establish the exclusive efficiency of EEOND because of potential competing effects from additional surgery or radiotherapy, it is noteworthy that EEOND successfully treated CON in more than one-third (36%) of our patients, obviating the need for further treatment. These findings underscore the value of our multimodal approach and emphasize the importance of prioritizing the minimally invasive option of EEOND whenever feasible.

In conclusion, our study demonstrates that EEOND is a safe procedure for treating nontraumatic CON associated with optic nerve compression at the level of the OC, even in cases of severe and longstanding visual impairment. Although our findings highlight EEOND as a viable alternative or complementary option in the multimodal treatment of skull base tumors invading the OC, further prospective studies with extended follow-up periods are needed to thoroughly evaluate its efficacy.

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Conception and design: R. Manet, C. F. Tilikete, E. Jouanneau; Acquisition of data: F. Calvanese, G. Jannelli, J. Fricker, S. Verrecchia; Analysis and interpretation of data: R. Manet, F. Calvanese, G. Jannelli, A. Delaidelli, S. Verrecchia, C. F. Tilikete, E. Jouanneau. Drafting the manuscript: R. Manet, F. Calvanese, G. Jannelli, A. Delaidelli; Revising the manuscript for intellectual content: R. Manet, S. Verrecchia, C. F. Tilikete, E. Jouanneau. Final approval of the completed manuscript: R. Manet, F. Calvanese, G. Jannelli, A. Delaidelli, J. Fricker, S. Verrecchia, C. F. Tilikete, E. Jouanneau.

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