



Postoperative severe visual impairment: surgical outcome of 165 patients with orbital tumours in the muscle cone

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Abstract

Objective This study aimed to evaluate the risk factors of postoperative severe vision impairment (PSVI) for a primary orbital tumour in the muscle cone.

Methods A retrospective analysis of the patients who underwent orbitotomy for primary intraconal tumours at the Tianjin Medical University Eye Hospital from January 2010 to December 2015.

Results A total of 165 cases of orbitotomy for primary orbital tumours in the muscle cone were included in the study. Postoperatively, 12 cases with vision acuity $\leq 20/400$ or ≥ 4 rows of vision decline and without any corrected effect were analysed as PSVI, including no light perception (NLP) for 3 cases. The multivariate logistic regression indicated that the tumour in orbital apex ($P = 0.048$, OR = 4.912, 95% CI: 1.011–23.866), severe optic nerve displacement ($P = 0.030$, OR = 6.007, 95% CI: 1.184–30.473) and intraoperative tight adhesion ($P = 0.003$, OR = 12.031, 95% CI: 2.282–63.441) were the independent risk factors for PSVI.

Conclusions The incidence of PSVI for the intraconal tumour was 7.3%, and the incidence of NLP was 1.8%. The tumour in orbital apex, severe optic nerve displacement and intraoperative tight adhesion were independent risk factors for PSVI.

Introduction

Postoperative severe vision impairment (PSVI) is the most serious complication of orbital surgery in the muscle cone. The central space in the orbit, which is limited by fascia of the eyeball, four rectus muscles, intermuscular membrane, and the common tendinous ring, contains many important structures, such as the optic nerve, ophthalmic artery and major branches. Previous studies have indicated that the incidence of vision loss varied from 0% to 24% [1–3], occurring after all types of orbital surgery, such as blowout orbital fracture repairing, orbital decompression, orbital

abscess drainage and tumour excision in the peripheral space or subperiosteal space. Importantly, the risk factors of vision impairment resulting from orbitotomy for intraconal tumours should be analysed to exclude confounding factor interference and make preoperative prediction more accurately. However, the analysis is difficult due to the low incidence of orbital tumours in the muscle cone. Therefore, long-term cooperation by case accumulation and follow-up is needed.

Cavernous haemangioma, venous haemangioma, schwannoma and so forth are the common primary tumours in this space. The risk of vision loss resulting from orbitotomy is different for tumours with varied characteristics. Mild impairment in visual acuity is common and can be recovered. However, severe vision impairment, including no light perception (NLP), is rare but cannot be recovered. The tumour size, location of tumour's posterior margin, optic nerve displacement, surgical route and tight adhesion to the surrounding tissue could be possible risk factors for vision loss, which should be proved by further analysing.

Therefore, this retrospective study was performed to determine the risk of PSVI based on the clinical data of 165 patients with intraconal tumours.

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Fig. 1 The location of the tumour's posterior margin on the largest section by horizontal CT scanning. **A** Tumour in the retrobulbar portion of the orbit, with the tumour's posterior margin not reaching the supraorbital fissure. **B** Tumour in the orbital apex, with the posterior boundary of lesion reaching the supraorbital fissure.

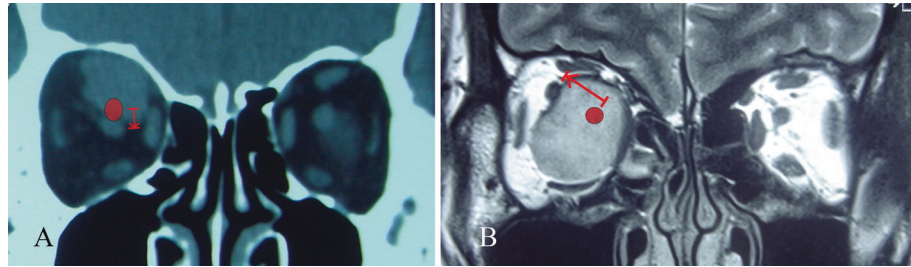
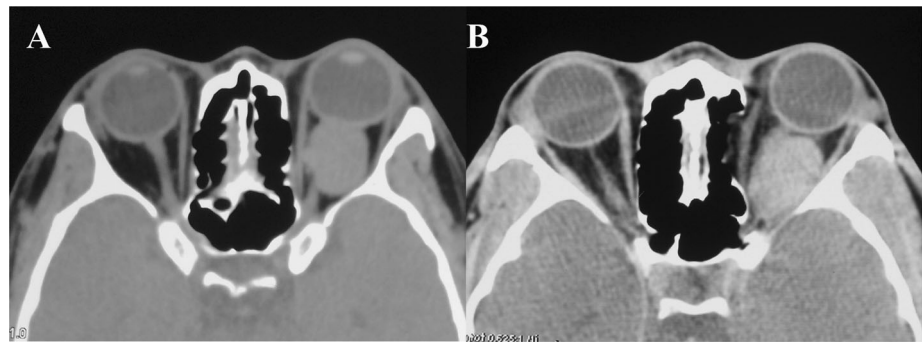


Fig. 2 The optic nerve compression and displacement on the maximum section by coronal CT/MRI scanning. **A** Mild displacement of the optic nerve. The red dot is the mirror image of the contralateral optic nerve, and the red arrow shows the displacement of the

ipsilateral optic nerve with about 1 MOND. **B** Severe displacement of the optic nerve. The red dot is the mirror image of the contralateral optic nerve, and the red arrow shows the displacement of the ipsilateral optic nerve with about >2 MOND.

Methods

The study was approved by Tianjin Medical University Eye Hospital Foundation Institutional Review Board and adhered to the principles of the Declaration of Helsinki. Informed consent was obtained from all included subjects. All patients who underwent orbitotomy for primary intraconal tumours at the Tianjin Medical University Eye Hospital from January 2010 to December 2015 were reviewed, retrospectively. The exclusion criteria were as follows: (1) the major coverage of orbital surgery in the peripheral or subperiosteal space, (2) primary fundus disease or optic neuropathy, or (3) preoperative vision <20/200 and without any corrected effect. Among the cohort, we identified cases with PSVI, which were evaluated according to the light perception monitoring on awaking (NLP) or postoperative vision ($\leq 20/400$ or ≥ 4 rows of vision decline and without any corrected effect). Controls were identified as other patients without PSVI in the cohort.

Demographic parameters were collected according to age, sex, time of onset, main signs and symptoms. Tumour characteristics were recorded, including pathology, maximum diameter, location, tumour compression and optic nerve displacement. The locations were classified into two types according to the tumour's posterior margin on the largest section by horizontal CT scanning: (1) retrobulbar tumour: The posterior boundary of the lesion was located in the retrobulbar space, but did not reach the supraorbital

fissure (Fig. 1a). (2) orbital apex tumour: The posterior boundary of the lesion reached or exceeded the supraorbital fissure or the opening of the optic nerve canal (Fig. 1b). The optic nerve displacement was analysed according to the maximum section of tumour on coronal CT/MRI imaging. The displacement was measured as follows: a mirror image of the contralateral optic nerve was made using Photoshop CC, the distance between the mirror image and the affected optic nerve was measured and expressed as multiples of the optic nerve diameter (MOND). To analyse the degree of optic nerve displacement, the data ≥ 75 th percentile indicated severe displacement, and ≤ 75 th percentile indicated mild displacement, respectively (Fig. 2).

The surgeries were performed by the same team of ophthalmologists. Intraoperative processes were collected, including surgical approach, complete resection, tight adhesion, excessive bleeding, abnormal pupil size, and disappearance of direct or indirect light reflection. Postoperatively, light perception monitoring was done every 1–2 h for the first 48 h bandage compression. After bandage removal, vision acuity was tested using the Snellen chart, and the changes in values and rows before and after surgery were recorded regularly for 1 month.

Statistical analysis

The risk factors for PSVI were analysed using SPSS Statistics 25 (NY, USA). Continuous variables were expressed

Table 1 Clinical characteristics and vision result of the study population.

Variables	Total (N = 165)	No PSVI (n = 153)	PSVI (n = 12)	P value
Age (year)	45.5 ± 17.5	46.0 ± 17.6	39.0 ± 17.4	0.186*
Male gender	76 (46.1)	71 (46.4)	5 (41.7)	0.751 [†]
Time of onset (month)	4.0 (23.0)	5.0 (23.0)	2.5 (4.5)	0.058 [§]
Preoperative complaint of vision decline	29 (17.6)	24 (15.7)	5 (41.7)	0.060 [†]
Preoperative abnormal fundus	6 (3.6)	4 (2.6)	2 (16.7)	0.062 [‡]
Proptosis (mm)	3 (2)	3 (2)	3 (2.5)	0.181 [§]
Tumour pathology				
Cavernous haemangioma	83 (50.3)	77 (50.3)	6 (50.0)	0.395 [‡]
Venous haemangioma	33 (20.0)	31 (20.3)	2 (16.7)	
Lymphoma	29 (17.6)	28 (18.3)	1 (8.3)	
Schwannoma	15 (9.0)	12 (7.8)	3 (25.0)	
Solitary fibrous tumour	5 (3.0)	5 (3.3)	0	
Max diameter (mm)	23 (8)	22 (7)	28 (12)	0.057 [§]
Tumour in orbital apex	33 (20.0)	24 (15.7)	9 (75.0)	<0.001 [†]
Severe optic nerve displacement	41 (24.8)	32 (20.9)	9 (75.0)	<0.001 [†]
Route of orbitotomy				
Anterior	121 (73.3)	118 (77.1)	3 (25.0)	0.001 [‡]
Lateral	41 (24.8)	32 (20.9)	9 (75.0)	
Transcranial	3 (1.8)	3 (2.0)	0	
Intraoperative tight adhesion	12 (7.3)	7 (4.6)	5 (41.7)	0.001 [‡]
Complete resection	138 (83.6)	128 (83.6)	10 (83.3)	0.976 [†]

PSVI postoperative severe vision impairment, MOND multiples of the optic nerve diameter.

*P values were derived from Student's *t* test.

[†]Chi-square test.

[‡]Fisher exact test.

[§]Mann–Whitney U test.

P < 0.05 was considered to be statistically significant.

as mean ± standard deviation (SD) or median (interquartile range) according to the normality tests. Categorical variables were expressed as number (percentage). Categorical variables were compared using the chi-square test of Fisher exact test. The Student's *t* test or the Mann–Whitney *U* test, where appropriate, was used to compare continuous variables between two groups. The univariate and multivariate logistic regression was used to analyse the relationship between PSVI and related characteristics to select the risk factors. The variables in univariate analysis at a significance level of *P* < 0.10 were then analysed in a stepwise multivariate logistic regression model. Finally, variables were defined as significant at the *P* < 0.05 level in the multivariate analysis.

Results

Basic characteristics of the study population

A total of 165 patients who underwent orbitotomy for primary orbital tumours in the muscle cone were included in

the study. Postoperatively, 12 patients were diagnosed with PSVI, including 20/400 for 1 patient, CF for 2 patients, HM for 3 patients, LP for 3 patients, and NLP for 3 patients. Three cases of NLP were detected on awakening by light perception monitoring, the others with vision loss were found 12–72 h after surgery. The total incidence of PSVI was 7.3%, and the incidence of NLP was 1.8%. Age, sex, time of onset, proptosis, preoperative complaint of vision decline and abnormal fundus were similar between the groups with and without PSVI (Table 1).

Tumour characteristics

The proportion of orbital apex tumour and severe optic nerve displacement were significantly higher in PSVI group (*P* < 0.001). Twenty per cent of tumours were in the orbital apex, including seven with cranio-orbital communicating tumours (three cavernous haemangioma, two solitary fibrous tumours, one venous haemangioma, and one schwannoma) that expanded from the supraorbital fissure or optic nerve canal into the skull base. The median of optic nerve displacement was 1.4 MOND (interquartile range:

Table 2 Logistic regression analysis of the risk factors for postoperative severe vision impairment.

Independent variables	Univariate			Multivariate		
	Odds ratio	95% CI	<i>P</i>	Odds ratio	95% CI	<i>P</i>
Age (year)	0.978	0.945–1.011	0.187			
Male gender	1.212	0.368–3.988	0.751			
Time of onset (month)	0.944	0.871–1.023	0.158			
Preoperative complaint of vision decline	3.839	1.125–13.103	0.032			
Preoperative abnormal fundus	7.450	1.214–45.711	0.030			
Proptosis (mm)	1.235	0.910–1.677	0.175			
Tumour pathology						
Cavernous haemangioma			0.455			
Venous haemangioma	0.828	0.158–4.327	0.823			
Lymphoma	0.458	0.053–3.977	0.479			
Schwannoma	3.208	0.706–14.574	0.131			
Solitary fibrous tumour	<0.001	–	0.999			
Max diameter (mm)	1.050	0.984–1.120	0.141			
Tumour in orbital apex	16.125	4.067–63.927	<0.001	4.912	1.011–23.866	0.048
Severe optic nerve displacement	11.344	2.901–44.352	<0.001	6.007	1.184–30.473	0.030
Route of orbitotomy						
Anterior			0.003			
Lateral	11.062	2.829–43.265	0.001			
Transcranial	<0.001	–	0.999			
Intraoperative tight adhesion	14.898	3.765–58.956	<0.001	12.031	2.282–63.441	0.003
Complete resection	1.024	0.211–4.959	0.976			

The variables were given at the $P < 0.05$ level in a stepwise multivariate logistic regression. *MOND* multiples of optic nerve diameter.

0.8–2.2 *MOND*). Segregated by the data at 75th percentile, 41 cases were regarded as severe displacement. The optic nerve in coronal CT/MRI showed compression deformation and displacement to the edge of muscle cone or orbital cavity in severe displacement cases. There were no significant differences in tumour pathology and maximum tumour diameter in two groups.

Intraoperative processes and vision complication

PSVI occurred in 3 of the 121 anterior orbitotomy patients and 9 of 41 lateral orbitotomy patients, no PSVI was found in transcranial orbitotomy patients. Intraoperatively, 12 patients with large or orbital apex tumours, including 4 with venous haemangioma, 3 with cavernous haemangioma, 3 with schwannoma, 1 with lymphoma, and 1 with solitary fibrous tumours, had tight adhesion to the area of surgical separation between the posterior margin and optic nerve, fascia, or periosteum in the apex. The surgical route and severe adhesion were both associated with PSVI ($P = 0.001$), lateral orbitotomy posed a higher risk of PSVI compared with anterior and transcranial orbitotomy. Twenty-seven cases of diffuse tumour (25 lymphomas, 2 venous haemangiomas) in the orbit were incomplete resection,

other cases of well-circumscribed mass were complete resection, the proportion of complete resection were similar between the groups with and without PSVI.

The risk factors and causes associated with PSVI

The risk factors were compared between the two groups using univariate and multivariate analyses (Table 2). After removal of the influence of confounding factors, tumour in orbital apex ($P = 0.048$, OR = 4.912, 95% CI: 1.011–23.866), severe optic nerve displacement ($P = 0.030$, OR = 6.007, 95% CI: 1.184–30.473) and intraoperative tight adhesion ($P = 0.003$, OR = 12.031, 95% CI: 2.282–63.441) remained significant independent variables of PSVI on multivariate analysis.

The reasons for PSVI could be intraoperative injury to the optic nerve/artery in four patients, central retinal artery occlusion (CRAO) in one patient, retrobulbar haematoma and high intraorbital pressure in one patient, and uncertain reason in six patients, which might be central retinal artery spasm (CRAS) and/or posterior ischaemic optic neuropathy (PION) (Table 3). The injury to the optic nerve or ocular artery branches occurred after dissection of the tumour's posterior margin close to the optic nerve, which was

Table 3 Clinical data of 12 cases with postoperative severe vision impairment.

NO.	Tumour	Maximum diameter (mm)	Location of posterior boundary	Optic nerve displacement	Orbitotomy	Tight adhesion	Pupil (mm)	Light reflex	UCVA ^a	Preoperative abnormal fundus	UCVA ^b	Cause of severe visual impairment
1	CH	30	Orbital apex	Severe	Lateral		5	Slow	20/40	Optic disk oedema	CF	Uncertain, CRAS/ PION
2	CH	28	Retrobulbar	Severe	Lateral	+	5	Disappeared	20/20		NLP	Intraoperative injury to optic nerve/artery
3	CH	34	Orbital apex ^c	Severe	Lateral	+	4	Disappeared	20/50		LP	Uncertain, CRAS/ PION
4	CH	15	Retrobulbar	Mild	Anterior		4	Slow	20/20		LP	Uncertain, CRAS/ PION
5	CH	27	Orbital apex	Severe	Lateral		5	Slow	20/20		20/400	Uncertain, CRAS/ PION
6	CH	27	Orbital apex	Severe	Lateral	+	5	Disappeared	20/100		NLP	Uncertain, CRAS/ PION
7	VH	36	Orbital apex	Severe ^d	Lateral		5	Slow	20/20		LP	Intraoperative injury to optic nerve/artery
8	VH	38	Orbital apex	Severe ^d	Anterior	+	4	Disappeared	20/100		HM	Postoperative haematoma and optic nerve compression
9	DLBCL	21	Orbital apex	Severe	Anterior		4	Disappeared	20/200	Optic disk oedema	NLP	Uncertain, CRAS/ PION
10	Schwannoma	16	Orbital apex	Severe	Lateral		6	Disappeared	20/200		HM	Intraoperative injury to optic nerve/artery
11	Schwannoma	21	Orbital apex	Severe	Lateral	+	6	Disappeared	20/200		HM	Intraoperative injury to optic nerve/artery
12	Schwannoma	29	Retrobulbar	Severe	Lateral		5	Slow	20/40		CF	CRAO

CH cavernous haemangioma, CRAO central retinal artery occlusion, CRAS central retinal artery spasm, DLBCL diffuse large B-cell lymphoma, PION posterior ischaemic optic neuropathy; VH venous haemangioma.

^aUCVA uncorrected vision acuity before surgery.

^bUCVA uncorrected vision acuity after surgery.

^cThe orbital apex tumour expanded into the skull base via the optic nerve canal.

^dThe optic nerve with severe displacement was surrounded and compressed by the tumour.

identified by incomplete optic nerve sheath, moderately dilated pupil, relative afferent pupillary defect, with or without excessive bleeding. CRAO/CRAS/PION, with no direct injury to optic nerve, occurred due to excessive compression, traction, vasospasm, controlled hypotension, or uncertain reasons. One patient with venous haemangioma (patient 8) was identified by excessive intraoperative haemorrhage (800 mL) and postoperative haematoma (48 h after bandage removal). The patient received emergency lateral canthotomy, cantholysis and drainage to reduce the high intraorbital pressure, and the vision improved to HM. Glucocorticoids pulse therapy was given to all cases with PSVI, however, no obvious improvement was observed at 1-month follow-up.

Discussion

In the present series of 165 patients who underwent orbitotomy for intraconal tumours, the incidence of PSVI was 7.3% (12/165) and that of NLP was 1.8% (3/165). Both were higher than the rate for all kinds of orbital disease reported by Bonavolonta (blindness, 0.44%) [2], Jacobs (vision loss, 0.84%) [4], Rose (vision loss, less than 1%) [5] and Kansakar (vision loss, 4.7%) [6], suggesting that the risk of surgery-specific vision loss was obviously higher in intraconal tumours. The tumours in the muscle cone, which account for the majority in orbital tumours, cause direct compression or adhesion to the optic nerve, ophthalmic artery, and other important structures. As a result, PSVI occurs under the influence of multiple factors.

There is little mention in the literature of analysis of optic nerve displacement, and this is an important relationship between the orbital tumour and optic nerve that requires further study. Our indirect measurement with mirror image allowed an assistive method to evaluate the optic nerve displacement in coronal. A large extent of displacement meant a tight correlation between the optic nerve and tumour, as well as an obvious change in the original anatomical position of the optic nerve and arteries. Any resection alongside the optic nerve or dissection at the orbital apex could bring high risk of vision loss. Rose et al. [5] reported 14 cases of postoperative vision loss, representing less than 1% of orbital surgery, including 10 cases involving directly surgical contact with the optic nerve (4 in orbital apex, 6 in surrounding optic nerve). We found that the cases with MOND at 75th percentile, which indicated severe optic nerve displacement, had a sixfold higher risk of PSVI. In horizontal CT/MRI imaging, the location of tumour's posterior margin was given more attention, and the tumour in orbital apex was also a stable risk factor for PSVI.

In the present study, patients with tight adhesion might have a twelvefold higher risk of PSVI. Severe adhesion of cavernous haemangioma could be predicted on horizontal CT imaging according to the tumour filling the orbital apex and disappearance of the transparent triangle region [7]. Tight adhesions are more likely to be found in removing tumours with dense fibrous contacts with orbital apex periosteum or surrounding the optic nerve, which should be resolved with careful dissection under suitable surgical approach [8, 9]. Anterior orbitotomy by transcutaneous or transconjunctival incision has been proposed to access the anterior and retrobulbar space [10]. Lateral orbitotomy can further enhance the exposure to the lateral, retrobulbar and lateral orbital apex by removal of zygomatic bone or deep sphenoid wing [11, 12]. Several transcranial approaches or endoscopic transnasal approach have been used in removal of tumours located in the medial orbit, orbital apex, optic canal, and adjacent extradural structure [13–16]. Jacobs et al. [4] reported 1665 cases of orbitotomy and found the vision loss was significantly more likely for patients undergoing endoscopic trans-sphenoidal approach to the optic canal (1/10, 10%) or intracranial approach to the orbital roof (4/22, 18.2%), lateral orbitotomy did not pose a significantly different risk of vision loss compared with anterior orbitotomy. In our series, the 22% incidence of PSVI in lateral orbitotomy patients was significantly higher than the incidence in anterior and transcranial approaches, which reflected the risks when dealing with intraconal tumour close to the orbital apex and those extension to the skull base through the supraorbital fissure. However, the surgical approach was not an independent risk factor for PSVI in multivariate analysis. Personal experiences of safe resection against tight adhesion could have a positive effect on the visual outcome. Other alternative management, such as subtotal resection, local decompression, are occasionally selected for cases where the whole lesion could not be removed from orbital apex [17].

PSVI is mainly caused by damage to the optic nerve or ophthalmic artery branches during dissection of the tumour posteriorly close to the optic nerve. It could be related to direct injury caused by excessive traction, blind dissection, repeated electric cautery or packing in the orbital apex, as well as indirect reasons of compressive or ischaemic optic injury, such as retrobulbar haematoma, high orbital pressure, controlled hypotension, spasm or occlusion of the central retinal artery [6, 18–20]. According to a large series of orbitotomies, PION is the main reason for postoperative vision loss, which may be related to postoperative vasospasm induced by extravasated blood and inflammatory mediators [5]. Besides, excessive or long-time compression and traction by brain spatula could also play a contributing factor of optic nerve ischaemia in patients 1, 3, 4, 5, 6 and 9. Postoperative haematoma could occur in patients with

anticoagulant usage, especially for those with orbital trauma [21]. The reasons for haematoma in patient 8 could be extensive resection, early removal of bandage and rebleeding of residual lesions. The emergency lateral canthotomy, cantholysis, and drainage could remove the haematoma and reduce the vision impairment by sudden space-occupying or high intraorbital pressure [22].

The present study still had some limitations. The sample size was small, the coverage of orbital diseases was not comprehensive, and the cases of endoscopic and transcranial approaches were very few, leading to possible bias and error. Therefore, a larger number of patients, probably in a multicentre study, are needed to verify the findings.

Conclusions

The incidence of PSVI for intraconal tumours was 7.3%, and the incidence of NLP was 1.8%. Postoperative severe vision loss was related to the influence of multiple factors. The tumour in orbital apex, severe optic nerve displacement and intraoperative tight adhesion remained significantly independent variables of PSVI on logistic regression analysis.

Summary

What was known before

- Postoperative severe vision impairment is the most serious complication of orbital surgery in the muscle cone.

What this study adds

- The incidence of severe visual impairment after orbitotomy for the intraconal tumour was 7.3%, and the incidence of NLP was 1.8%.
- The tumour in orbital apex, severe optic nerve displacement and intraoperative tight adhesion were independent risk factors for postoperative severe visual impairment.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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