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Forced duction training

A potential key point for recovery in pediatric patients with trapdoor fracture

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Abstract

Trapdoor fracture is a type of orbital fracture frequently observed in pediatric patients after facial trauma. The treatment options and surgical outcomes associated with this fracture are controversial.

This study investigated the surgery principles and strategies as well as the functional training for the recovery and prognosis of pediatric patients with trapdoor fracture.

A retrospective study was conducted on 21 pediatric patients with orbital trapdoor fracture who received the transconjunctival approach for orbital defect reconstruction surgery between 2009 and 2014 at the Department of Ophthalmology, Shanghai Ninth People's Hospital. The minimum follow-up period was 1 year, and the average follow-up time was 2.5 years. These data included surgery principles and strategies, functional training for recovery, and patient prognosis.

Of all the numerical variables, interval to surgery was the only parameter that affected the recovery of ocular movement and diplopia grades [ΔLEMSG (6 m:pre) = -2.689 + 0.015 • interval to surgery, $P=0.018$; ΔLEMSG (last:pre) = −3.171 + 0.026 • interval to surgery, $P=0.033$; Δdiplopia (6 m:pre) = −3.266 + 0.026 • interval to surgery, $P=0.047$; Δdiplopia (last:pre) = −2.518 + 0.019 • interval to surgery, $P=0.031$], whereas recovery was not affected by age or preoperative ocular movement or diplopia grades ($P>0.05$). According to the categorical variable analysis, patient prognosis grouped by coordination to forced duction training varied across the different groups ($P<0.05$); however, male and female patients did not differ with regard to prognosis ($P>0.05$).

To judge the prognosis of pediatric patients with trapdoor fracture, cooperation to forced duction training and interval to surgery are most likely key points. Correct surgical approaches and functional training are of great importance for faster recovery.

Abbreviations: BFC = bad-forced duction training-cooperated, CT = computed tomography, L+D = sum of the LEMSG and diplopia, LEMSG = Limitation of extraocluar movement in superior gazing, WFC = well-forced duction training-cooperated.

Keywords: forced duction, pediatrics, trapdoor fracture

1. Introduction

A trapdoor fracture is a special type of orbital floor fracture typically observed in pediatric patients in which the orbital contents are herniated and trapped through the medial hinged fracture site.[1] Because of the clamping of the inferior rectus muscle and surrounding tissue, severe diplopia and oculocardiac reflex can occur. The overall incidence of trapdoor fracture in pediatric patients is much lower than that in adults because of the differences in their sinus wall thickness, cheek fat pad size, and other anatomical and physiological features of facial development.[2,3]

Forced induction testing, also known as the passive traction test, is a simple and useful examination to judge the presence of ocular motility mechanical restriction; however, it is seldom used for functional recovery training.[4,5] A positive result for forced induction testing, in addition to diplopia within 30° of the primary position and large defects involving more than 50% of the orbital floor are considered as general indications for surgery.[6] In surgical intervention, the absolute dissociation of entrapped and herniated muscle and tissue is vital. Otherwise, the most frequently observed symptoms, extraocular movement limitation and diplopia, will continue.[4]

Recently, studies of trapdoor fracture have primarily focused on surgery indications, early treatments, the effect of age on prognosis, and large-scale epidemiological analyses. In these studies, patients were either grouped by age or the time interval between injury and operation. However, contradictory conclusions have been reported.[4,7,8] The aim of the current study was to investigate the importance of forced duction training on surgery principles and strategies as well as the recovery and prognosis of pediatric patients with trapdoor fracture.

In our opinion, the advantages of transconjunctival surgery for trapdoor fracture have not been well discussed in the scientific literature. Moreover, forced duction testing has not been defined as an important postoperative recovery method, nor has forced

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duction training cooperation been deemed as a key point for recovery in patients with trapdoor fracture.

2. Methods

The current study followed the tenets of the Declaration of Helsinki, and the local ethics committee of our university approved the study protocol.

2.1. Epidemiology and the inclusion and exclusion criteria

In this retrospective study, the data from 21 pediatric patients (21 eyes) with orbital trapdoor fracture who received the transconjunctival approach for orbital defect reconstruction surgery at the Shanghai Ninth People's Hospital between 2009 and 2014 were analyzed after approval was received from the internal review board.

Patients under the age of 18 with computed tomography (CT)-certified trapdoor fracture, possible nausea and vomiting immediately after injury, restriction on extraocular movement, diplopia, and minimal soft tissue swelling and ecchymosis were included in this study (25 eyes from 25 patients were initially enrolled). Patients with a best corrected visual acuity less than 0.3 or visual loss, previous surgical repair, enophthalmos, strabismus before trauma, complex orbital fractures, or bilateral orbital fractures as well as incomplete clinical and CT evidence were excluded (Four eyes from 4 patients were excluded from the initial 25 patients). Furthermore, patients who received non-anatomical reduction after surgery certified via CT were also excluded.

Of the 21 patients enrolled in this study, 16 were boys and 5 were girls. The time interval from injury to surgery of each patient was 14.7 ± 11.9 days in total. The shortest follow-up duration was 1 year, and the average follow-up duration was 2.5 years.

2.2. Assessment

Limitation of extraocluar movement in superior gazing (LEMSG) grade and diplopia level grade were assessed in this study at 3 time points: before surgery, 6 months after surgery, and at the last follow-up. LEMSG level was graded using the distance between the posterior corneal limbus margin and the line joining both canthus of one eye during the superior gaze direction. Grade 0 denoted perfect movement, whereas Grades 1, 2, 3 represented movement limitations of 1, 2, and 3 mm, respectively. According to Nagy principle, diplopia level was assessed such that Grade 0 denoted no diplopia; Grade 1 represented diplopia only in the peripheral vision when gazing beyond 30°; Grade 2 denoted diplopia in the forward, downward, or both directions even when gazing within 30°; and Grade 3 represented diplopia in all gazing directions.[9] After adding the LEMSG and diplopia grades (L+D), Grades 0 and 1 were considered as representing full recovery, whereas Grade 2 indicated an almost complete recovery.

2.3. Treatment

Transconjunctival surgery was performed on every patient. Through the lower border of the tarsal plate, dissection proceeded down to the lower lid retractors. Afterward, the orbicularis oculi and orbital septum were bluntly dissected to expose the inferior orbital rim. Then, the periosteum was incised along the gray line to expose the fractured bone and the herniated orbital tissue. All of the borders of the fracture site were sufficiently exposed, and all entrapped tissues, rectus, and the infraorbital neurovascular bundle were carefully disassociated and pulled back followed by the reposition of this hinge-like green-stick fracture. The hinge-like structure was thoroughly protected from further damage, and a biodegradable mesh (RapidSorb; Synthes, West Chester, PA) was applied afterward to patch the defect against the downward tension from the orbital contents, preventing postoperative herniation and entrapment.[10] Forced duction testing should be performed at the end of surgery to confirm the complete release of the entrapped tissue.

During the first 2 weeks after surgery, forced duction training was performed daily on patients after a thorough explanation. The procedure was performed after local anesthesia of 0.4% oxybuprocaine hydrochloride eye drops was applied. In addition, active functional training was introduced to the patients and their guardians to guarantee a favorable prognosis.

2.4. Statistical analysis

A multiple linear regression analysis and Pearson correlation coefficient r was used to identify the potential parameters that change the LEMSG and diplopia grades. The Chi-square test was used for categorical variable analysis. A P value of <0.05 was considered significant. All statistical analyses were performed using SPSS 13.0 (SPSS Inc., Chicago, IL).

3. Results

Twenty-one pediatric patients were admitted to the Shanghai Ninth People's Hospital over the 6-year period with orbital trapdoor fracture and received the transconjunctival approach for orbital defect reconstruction surgery. The descriptive information for the patients is provided in Table 1.

Table 2 provides the descriptive information for the LEMSG and diplopia grade changes from the preoperative assessment to the 6-month postoperative follow-up and from the preoperative assessment to the final follow-up evaluation. The mean changes in the LEMSG and diplopia grades were ΔLEMSG (6 m:pre) = −1.29, ΔLEMSG (last:pre) = −1.67, Δdiplopia (6 m:pre) = -0.67, and Δdiplopia (last:pre) = −1.05.

Potential predictive parameters that would alter the change in LEMSG grade and diplopia grade are presented in Table 3. The parameters are based on a multiple linear regression model, which was restricted to the relevant dependencies only. The mean values of ΔLEMSG (6 m:pre), ΔLEMSG (last:pre), Δdiplopia (6 m:pre), and Δdiplopia (last:pre) showed a negative linear dependency on interval to surgery when the regression coefficient was positive. These results indicate that an increase in the interval to surgery resulted in a reduced decrease in LEMSG or diplopia grade, representing a worse recovery.

When the patients were grouped according to their coordination to forced duction training or according to gender, the L+D grade (sum of the LEMSG and diplopia grade) was applied to assess the comprehensive restoration of the patients. The results of this categorical variables analysis are presented in Table 4. The results indicated that the recovery of patients in the well-forced duction training-cooperated (WFC) and bad-forced duction training-cooperated (BFC) groups significantly differed at the 6-month time point ($P < 0.05$). Gender did not affect patient recovery ($P > 0.05$).

Table 1

Descriptive patient information.

Patient no.	Age, y	Sex (M/F)	Interval to surgery (days)	Forced duction testing cooperation	LEMSG grade[1] Preoperative	LEMSG grade[1] 6-month postoperative	LEMSG grade[1] Last follow-up	Diplopia grade[1] Preoperative	Diplopia grade[1] 6-month postoperative	Diplopia grade[1] Last follow-up	Sum of LEMSG and diplopia grades[1] Preoperative	Sum of LEMSG and diplopia grades[1] 6-month postoperative	Sum of LEMSG and diplopia grades[1] Last follow-up
1	6	M	3	Good	2	0	0	3	0	0	5	0	0
2	11	M	15	Good	1	1	0	2	0	0	3	1	0
3	9	M	26	Good	1	0	0	2	0	0	3	0	0
4	13	M	1	Good	1	1	1	1	0	0	1	1	1
5	15	F	11	Good	0	0	0	1	0	0	2	0	0
6	11	M	8	Good	2	0	0	2	2	0	4	2	0
7	8	M	15	Good	1	0	0	3	0	0	4	0	0
8	8	F	16	Good	2	2	1	3	2	2	5	4	3
9	14	M	4	Good	2	1	1	1	0	0	3	1	1
10	12	F	4	Good	2	1	1	1	0	0	3	1	1
11	6	M	15	Good	1	1	0	2	0	0	3	1	0
12	12	F	11	Good	2	1	1	2	0	0	4	1	1
13	16	M	38	Good	3	2	0	2	0	0	5	2	0
14	9	M	29	Good	2	1	1	3	1	0	5	2	1
15	11	M	16	Poor	2	1	1	3	2	0	5	3	1
16	14	M	44	Poor	2	0	0	2	1	0	4	1	0
17	7	M	2	Poor	1	1	1	1	0	0	2	1	1
18	5	F	13	Poor	2	2	1	3	2	2	5	4	3
19	10	M	5	Poor	2	1	0	1	1	0	3	2	0
20	11	M	6	Poor	1	1	1	2	1	1	3	2	2
21	7	M	28	Poor	3	3	3	2	1	0	5	4	3

LEMSG = Limitation of extraocular movement in superior gazing.

Table 2

Changes in LEMSG and diplopia grades.

	ΔLEMSG (6 m:pre)[1]	ΔLEMSG (last:pre)[1]	Δdiplopia (6 m:pre)[1]	Δdiplopia (last:pre)[1]
Mean ± SD	−0.67 ± 0.66	−1.05 ± 0.80	−1.29 ± 0.90	−1.67 ± 0.91
Median	−1.00	−1.00	−1.00	−2.00
Min − max	−2.00–0	−3.00–0	−3.00–0	−3.00–0

LEMSG = limitation of extraocular movement in superior gazing.
ΔLEMSG (6 m:pre): change in LEMSG from the preoperative assessment to the 6-month postoperative follow-up evaluation.
ΔLEMSG (last:pre): change in LEMSG from the preoperative assessment to the last follow-up evaluation.
Δdiplopia (6 m:pre): change in the limitation of extraocular movement from the preoperative assessment to the 6-month postoperative follow-up evaluation.
Δdiplopia (last:pre): change in limitation of extraocular movement from the preoperative assessment to the last follow-up evaluation.

Table 3

Potential predictors that affect the change in the LEMSG and diplopia grades.

ΔLEMSG or Δdiplopia	Preoperative parameters or descriptive information	Constant	Age, y	Interval to surgery, d	Preoperative LEMSG grade [1]	Preoperative diplopia grade[1]
ΔLEMSG (6 m:pre)[1]	Regression coefficient	−2.689	3.01	0.015	0.289	1.355
	r	—	0.275	0.300	0.377	0.267
	P	0.015	0.178	**0.018**	0.187	0.216
ΔLEMSG (last:pre) [1]	Regression coefficient	−3.171	1.28	0.026	0.505	1.288
	r	—	0.180	0.397	0.118	0.512
	P	0.026	0.391	**0.033**	0.367	0.116
Δdiplopia (6 m:pre)[1]	Regression coefficient	−3.266	2.280	0.026	0.482	1.136
	r	—	0.275	0.397	0.256	0.267
	P	0.001	0.178	**0.047**	0.355	0.216
Δdiplopia (last:pre)[1]	Regression coefficient	−2.518	2.610	0.019	0.388	0.946
	r	—	0.133	0.512	0.417	0.211
	P	0.009	0.254	**0.031**	0.153	0.196

ΔLEMSG (6 m:pre): change in LEMSG from the preoperative assessment to the 6-month postoperative follow-up evaluation.
ΔLEMSG (last:pre): change in LEMSG from the preoperative assessment to the last follow-up evaluation.
Δdiplopia (6 m:pre): change in limitation of extraocular movement from the from the preoperative assessment to the 6-month postoperative follow-up evaluation.
Δdiplopia (last:pre): change in limitation of extraocular movement from the preoperative assessment to the last follow-up evaluation.
Regression coefficient in the first row of each ΔLEMSG or Δdiplopia parameter is represented with a linear regression function (e.g., ΔLEMSG [6m:pre] = -2.689 + 0.015 • interval to surgery).
r refers to the correlation coefficient.
P refers to the significance level.
Significant values are indicated in bold.
LEMSG = Limitation of extraocular movement in superior gazing.

Table 4

Restoration of the patients grouped by coordination to forced duction training or gender.

	Group	Complete and almost complete recovery (n)	No recovery (n)	k^2	P
6 months	WFC	13	1	4.72	**0.03** $<$ *P* $<$ **0.05**
	BFC	4	3		
Last follow-up	WFC	13	1	1.75	0.10 $<$ *P* $<$ 0.25
	BFC	5	2		
6 months	Males	14	2	1.87	0.10 $<$ *P* $<$ 0.25
	Females	3	2		
Last follow-up	Males	15	1	3.54	0.05 $<$ *P* $<$ 0.10
	Females	3	2		

Significant values are presented in bold.

Almost complete recovery = L+D grade = 2, BFC = bad-forced duction training-cooperated, Complete recovery = L+D grade = 0 or 1, L+D grade = sum of the LEMSG and diplopia grades, No recovery = L+D grade $>$ 2, WFC = well-forced duction training-cooperated.

4. Discussion

A total of 21 pediatric patients with orbital trapdoor fractures who underwent surgical correction were studied. Because of the fracture type included in this study, inferior rectus muscle movement might represent the level of extraocular movement.[11,12] By collecting descriptive information from the patients, we analyzed the potential predictors that might affect the changes in the LEMSG and diplopia grades via a multiple linear regression analysis. According to the results summarized in Table 3, we concluded that interval to surgery was the only parameter that influenced the change in the LEMSG and diplopia grades. Specifically, Table 2 summarizes that the means of ΔLEMSG (6 m:pre), ΔLEMSG (last:pre), Δdiplopia (6 m:pre), and Δdiplopia (last:pre) were negative and linearly depended on interval to surgery in a positive direction. These results indicate that an increase in the interval to surgery produced a smaller decrease in the LEMSG or diplopia grades, thereby representing a worse recovery. This result is consistent with previous studies that advocate early treatments for better trapdoor fracture prognosis.[13–15]

Neither age nor gender affected recovery speed or the therapeutic effect. Different researchers have taken disparate academic views regarding these aspects. From anatomical and mechanical points of view, Wei and Durairaj[16] and Alcalá-Galiano et al[2] suggested that children younger than 7 years old should be treated discriminately because of the protection mechanism of the orbital fracture in their thick sinus walls, larger cheek fat pads, and smaller mid-face areas compared with older children and adults. In addition, Su et al[5] argued that clinical presentations might also be distinct because of various social activities across different life stages and genders. Nevertheless, the data in Table 1 suggest that relatively few severe cases were observed in children aged 0 to 6 years. Moreover, male and female patients did not significantly differ in restoration according to the categorical variables analysis presented in Table 4. Importantly, patients with a best corrected visual acuity less than 0.3 were excluded from this study because poor vision might affect the assessment of diplopia.[17] Thus, this contradiction might be because of sample bias as well as the differences regarding the inclusion and exclusion criteria across disparate research.

The transconjunctival approach to surgery was administered rather than the subciliary or lower fornix approaches. First, young patients have greater aesthetic concerns than adults; thus, a transconjunctival incision is more acceptable than a subciliary incision. Second, the lower fornix approach considers that the orbital septum is more vulnerable to fat herniation and the disturbance of Loodwood ligament system. Third, our experience suggests that postoperative ectropion and scar hyperplasia generally result from incorrect sutures that fasten the orbital septum to the periosteum. These problems can be avoided using the transconjunctival approach because of the relative fixed anatomical sites.

Researchers have studied the prognosis of trapdoor fracture using various methods; however, proper postoperative training is rarely mentioned, especially with regard to forced duction training.[4,13] Here, forced duction training is not only a diagnostic examination but also a determining point for recovery training. Over the first 2 weeks following surgery, patients performed forced duction testing daily after local anesthesia. However, only 14 patients in this study cooperated, and the youngest patient was only 6 years old (Table 1).

To our knowledge, the extant academic literature has not documented passive functional training matched with the correct statistical analysis. On the basis of the categorical variable analysis presented in Table 4 and the multiple linear regression results in Table 2, we conclude that patients in the WFC group exhibited better restoration 6 months after the operation than those in the BFC group, regardless of age, gender, or the interval to surgery. Compared with other reports focusing on pediatric patients with trapdoor fracture, we observed a faster recovery period and better outcomes, especially for the WFC group.[13,18] This finding might be attributed to the use of appropriate surgical techniques and the adoption of passive recovery training.

As Alcalá-Galiano et al[2] noted, children are not small adults. Some changes should be made with regard to the therapeutic strategies and the research of pediatric orbital fracture based on the differences between adults and children. Forced duction training is employed by our surgical team after surgery as an important passive recovery technique, and a new grouping principle for prognosis research might represent a novel methodology that respects these differences. In addition to force duction training, patients of all ages performed voluntary functional training for all types of orbital fracture. This training primarily involves extraocular movement and gazing in various directions. From our experience, adults typically respond faster than children, which is consistent with the findings of other researchers.[19,20] We hypothesize that this difference is due to the better cooperation of adults during voluntary postoperative functional training than pediatric patients.

To the best of our knowledge, this research is the first to provide details of intraoperative and postoperative medical interventions in which the importance of the appropriate surgical technique and forced duction training for recovery was primarily illustrated and supported by the correct statistical analysis. However, additional research on pediatric patients with trapdoor fracture should be performed in a larger clinical population to reduce sample bias. Moreover, psychological analyses about forced duction training should be added to our treatment for pediatric patients.

References

[1] Grant JH III, Patrinely JR, Weiss AH, et al. Trapdoor fracture of the orbit in a pediatric population. Plast Reconstr Surg 2002;109:482–9.

[2] Alcalá-Galiano A, Arribas-García IJ, Martín-Pérez MA, et al. Pediatric facial fractures: children are not just small adults. RadioGraphics 2008;28:441–61.

[3] Oppenheimer AJ, Monson LA, Buchman SR. Pediatric orbital fractures. Craniomaxillofac Trauma Reconstr 2013;6:9–20.

[4] Yang JW, Woo JE, An JH. Surgical outcomes of orbital trapdoor fracture in children and adolescents. J Craniomaxillofac Surg 2015;43:444–7.

[5] Su Y, Shen Q, Lin M, et al. Diplopia of pediatric orbital blowout fractures: a retrospective study of 83 patients classified by age groups. Medicine (Baltimore) 2015;94:e477.

[6] Chandler DB, Rubin PAD. Developments in the understanding and management of pediatric orbital fractures. Int Ophthalmol Clin 2001;41:87–104.

[7] Jordan DR, Allen LH, White J, et al. Intervention within days for some orbital floor fractures: the white-eyed blowout. Ophthal Plast Reconstr Surg 1998;14:379–90.

[8] Gerbino G, Roccia F, Bianchi FA, et al. Surgical management of orbital trapdoor fracture in a pediatric population. J Oral Maxillofac Surg 2010;68:1310–6.

[9] Nagy EV, Toth J, Kaldi I, et al. Graves' ophthalmopathy: eye muscle involvement in patients with diplopia. Eur J Endocrinol 2000;142: 591–7.

[10] Lieger O, Schaller B, Zix J, et al. Repair of orbital floor fractures using bioresorbable poly-L/DL-lactide plates. Arch Facial Plast Surg 2010;12:399–404.

[11] Bansagi ZC, Meyer DR. Internal orbital fractures in the pediatric age group: characterization and management. Ophthalmol 2000;107: 829–36.

[12] Neinstein RM, Phillips JH, Forrest CR. Pediatric orbital floor trapdoor fractures: outcomes and CT-based morphologic assessment of the inferior rectus muscle. J Plast Reconstr Aesthet Surg 2012;65: 869–74.

[13] Wang NC, Ma L, Wu SY, et al. Orbital blow-out fractures in children: characterization and surgical outcome. Chang Gung Med J 2010;33: 313–20.

[14] Egbert JE, May K, Kersten RC, et al. Pediatric orbital floor fracture: direct extraocular muscle involvement. Ophthalmology 2000;107: 1875–9.

[15] Gerber B, Kiwanuka P, Dhariwal D. Orbital fractures in children: a review of outcomes. Br J Oral Maxillofac Surg 2013;51:789–93.

[16] Wei LA, Durairaj VD. Pediatric orbital floor fractures. J AAPOS 2011;15:173–80.

[17] World Health OrganizationGlobal Data on Visual Impairments. Geneva: World Health Organization; 2010.

[18] Feldmann ME, Rhodes JL. Pediatric orbital floor fracture. Eplasty 2012;12:ic9.

[19] Cope MR, Moos KF, Speculand B. Does diplopia persist after blow-out fractures of the orbital floor in children? Br J Oral Maxillofac Surg 1999;37:46–51.

[20] de Man K, Wijngaarde R, Hes J, et al. Influence of age on the management of blow-out fractures of the orbital floor. Int J Oral Maxillofac Surg 1991;20:330–6.