Effect of Time to Operative Intervention on Motility Outcomes Following Orbital Floor Fracture Repair in Children

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**ORIGINAL INVESTIGATION**

**Purpose:** To evaluate the relationship between time to surgical intervention and extraocular motility outcomes in children following repair of an orbital floor fracture with inferior rectus entrapment.

**Methods:** After institutional review board’s approval, a retrospective, consecutive case series of 28 children with unilateral orbital floor fractures entrapping the inferior rectus muscle was conducted. Clinical examinations and CT images were performed on all children. The main outcomes measured were postoperative motility measurements.

**Results:** Eleven patients underwent surgery within 24 hours of reported injury, while 17 patients underwent surgery after 24 hours. There was no statistically significant difference in average age at the time of surgery ($p = 0.47$) or average preoperative motility scores ($p = 1.0$) between the 2 groups. Patients who underwent surgery within 24 hours of reported injury had an improved likelihood of recovery (log hazard ratio = 0.469; 95% confidence interval, 0.42 to 1.36).

**Conclusions:** Our exploratory study suggests that surgical reduction of inferior rectus entrapment in pediatric orbital floor fractures within 24 hours from the time of injury shows an improved, but nonstatistically significant, likelihood of recovery in motility deficits with earlier surgical intervention.

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Orbital floor fractures in children typically occur due to blunt facial trauma. The inferior rectus muscle may become entrapped within a “trapdoor” fracture and lead to ischemia and fibrosis, thus causing irreversible scarring and permanent motility deficits. 1-4 The decision to operate is dependent primarily on the clinical examination as CT findings may underestimate soft-tissue entrapment or even fail to identify a fracture.5,6 Appreciation of the damage to the soft-tissue trapped within the fracture has prompted numerous publications. While recommendations vary for the timing of surgical repair of pediatric orbital fractures causing entrapment, 1,5 it is generally recommended to operate within 5 days and preferred within 48 hours of diagnosis.2

Previous studies have demonstrated that skeletal muscle cells start to develop irreversible damage with as little as 3 hours of ischemia.10-12 Given the risks of ischemia with inferior rectus entrapment, we hypothesize that immediate repair within 24 hours of orbital floor fractures with evidence of inferior rectus muscle entrapment results in improved preservation of extraocular motility.

**METHODS**

The protocol was approved by the Vanderbilt University Institutional Review Board and was compliant with the Health Insurance Portability and Accountability Act. The study adhered to the tenets of the Declaration of Helsinki. We conducted a retrospective review of all cases of pediatric orbital floor fractures that were evaluated at a Children’s Hospital and received follow-up care at the same institution from January 1, 2002, through December 31, 2014. Patients were identified by a search of the electronic billing system for an International Classifications of Disease, Ninth Revision diagnosis code of 802.6–9 (802.6 closed fracture of orbital floor, blowout, 802.7 open fracture of orbital floor, 802.8 closed fracture of other facial bones, and 802.9 open fractures of other facial bones). Cases were included if clinical findings were consistent with an orbital floor fracture with inferior rectus muscle entrapment without the need for any other facial fracture repair in children under 18 years of age at presentation. Cases were excluded if the patient did not undergo surgery or had received concomitant facial fracture repair.

Patient age, sex, laterality, mechanism of injury, symptoms, vision, additional injuries, CT findings, time of injury to surgical intervention, surgical intervention, and data from follow up visits including vision, symptoms, and motility were documented. The first postoperative endpoint evaluated was the appointment where resolution of the deficit was noted or the final appointment where motility deficits were present if the patient had not fully recovered, whichever came sooner. The final postoperative endpoint evaluated was the appointment where full motility was noted or the final appointment where motility deficits were present if the patient did not fully recover, whichever came sooner. While several different surgeons from ophthalmology, otolaryngology, and facial plastics services may have operated on the patients in this study, all patients received ophthalmology consultation prior to surgery and received at least 1 ophthalmology postoperative evaluation. Each physician based surgical management strategies on his or her clinical judgment.

Extraocular motility was judged on a subjective scale of 0 (normal eye movement) to –4 (no movement in the field of gaze). The summation of motility measurements in the vertical gazes was utilized to describe overall vertical motility, such that a patient with complete vertical limitation would have a motility score of –8.4

**Statistical Analysis**

Mean and standard deviation (SD) were reported for continuous variables. Count and frequency were reported for categorical variables. Characteristics of patients with and without immediate repair within 24 hours were compared using chi-square test for categorical covariates and Wilcoxon rank sum test for continuous variables. A Kaplan-Meier plot was generated for the time to recovery, and Cox proportional hazard model was used to evaluate the effect of immediate repair within 24 hours of injury. Statistical analysis was performed using R 3.3.0 (R Foundation for Statistical Computing, Vienna, Austria. 2016.). A significance level of 0.05 was chosen for all analyses.

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RESULTS

Charts of 28 children younger than 18 years, who had orbital floor fractures with clinical evidence of inferior rectus entrapment and underwent a surgical intervention were included for review in the study. Charts of 119 patients were excluded as they had either received concomitant facial fracture repair or were not operated on at all. There were total of 21 males and 7 females, with the average age of 12 years (range, 5–17 years; SD, 4.1). Eleven patients (39%), with an average age of 11.1 years (range, 6–7 years; SD, 3.7), underwent surgery within 24 hours of reported injury (range, 6–24 hours; mean, 16 hours; SD, 5.5 hours), while 17 patients (61%), with an average age of 12.3 years (range, 5–17 years; SD, 4.3), underwent surgery after 24 hours of reported injury (range, 25–670 hours; mean, 140 hours; SD, 189.2 hours). There was no statistically significant difference in age (p = 0.47).

CT scans from all patients were reviewed to confirm an orbital floor fracture. Ten of the 11 patients who underwent surgery within 24 hours were noted to have fractures of the trapdoor variety that were minimally or nondisplaced, while 1 had an open-strut, hinged fracture. Of the patients who underwent surgery after 24 hours, 3 patients had hinged fractures, while 14 patients had minimally or nondisplaced fractures (p = 0.52). All patients in this study had clinical evidence of inferior rectus entrapment prior to surgical intervention (Table).

All 11 patients who underwent surgery within 24 hours received an orbital implant during surgery. Four patients received a GELFILM Sterile Film implant (Pharmacia and Upjohn Company, Kalamazoo, MI). Six patients received a Suprafoil Suprafoil Nylon Foil implant (S. Jackson Inc., Alexandria, VA). One patient received both the GELFILM and Suprafoil implants. Of the patients who underwent surgery after 24 hours, 16 patients received an implant, while 1 patient had release of entrapped tissue without an implant. Ten patients received the GELFILM implant. Three patients received a MEDPOR Titan Implant (Stryker Corp., Kalamazoo, MI). Two patients received the Suprafoil implant. One patient received both Suprafoil and MEDPOR Titan implants.

Mechanism of injury varied with 12 patients injured during athletic activity, 3 patients injured after falling from a scooter, 5 patients injured in a fight, 2 patients injured from a fall, and 6 patients injured during a motor vehicle, all-terrain vehicle, or go-karting accident. Twenty patients had complained about diplopia on presentation, 3 patients were noted to have bradycardia, 5 patients presented with nausea and/or vomiting, and 2 patients had cheek hypoesthesia on the side of injury. One patient had a small hyphema, and 1 patient had a retrobulbar hematoma.

Patients who underwent surgery within 24 hours of injury had an average vertical preoperative motility of -3.23 (range, -0.5 to -7; SD, 2.0) in the affected eye. Patients who underwent surgery after 24 hours of injury had an average overall preoperative motility of -3.38 (range, -0.5 to -8; SD, 2.4) in the affected eye. There was no statistically significant difference between the 2 groups (p = 1.0).

Postoperative motility measurements from the first outpatient visit that either demonstrated resolution of deficits or at least 2 weeks, whichever came sooner, was utilized as the first postoperative endpoint for this study. Patients who had surgery within 24 hours had a mean of 31 days (range, 5–104 days) to the first postoperative endpoint, while those who underwent surgery after 24 hours had a mean of 43 days (range, 4–237 days) in this measure. Eight of 11 patients (73%) who had surgery within 24 hours were noted to have complete resolution of their motility limitations, while 3 patients had persistent limitations in vertical gaze. Eleven of the 17 patients (65%) who had surgery after 24 hours were noted to have complete resolution of their motility deficits. The average postoperative vertical motility at this first endpoint for patients who underwent surgery within 24 hours was -0.36 (range, 0 to -2; SD, 0.7). The average postoperative motility for patients who underwent surgery after 24 hours was -0.5 (range, 0 to -2; SD, 0.8). There was no statistically significant difference in the overall postoperative extraocular motility measurements (p = 0.69).

The final outpatient appointment where motility deficits had resolved or were still noted was also evaluated. Ten of 11 patients (90.9%) who had surgery within 24 hours were noted to have complete resolution of their motility limitations, while 1 patient, who did undergo a postoperative orbit CT to confirm successful surgical reduction of the fracture, had persistent limitations in vertical gaze at the final visit. Thirteen of the 17 patients (76.5%) who had surgery after 24 hours were noted to have complete resolution of their motility deficits, while 4 patients had residual vertical motility deficits at their final visits. One of these patients underwent additional strabismus surgery after a postoperative orbit CT. Two of these patients underwent postoperative orbit CT to confirm successful surgical reduction of the fracture. One patient did not return for additional examinations or testing after the final outpatient appointment at which residual deficits were noted.

For the 23 patients with full recovery at their final outpatient appointment, the group of 10 that underwent surgery within 24 hours had complete resolution after an average of 44.4 days (range, 5–104 days; SD, 39.1), while the group of 13 that underwent surgery after 24 hours had complete resolution after an average of 99.5 days (range, 4–777 days; SD, 214.0). A Kaplan-Meier plot was generated in Figure 1. Cox proportional hazard model assuming interval censoring led to a positive log hazard ratio estimate of 0.469 (95% confidence interval, 0.42 to 1.36; p = 0.298), which indicates that operating within 24 hours improves the likelihood of complete recovery in motility deficits, but is not statistically significant.

DISCUSSION

The evaluation and management of pediatric orbital floor fractures requires thorough physical examination (Fig. 2) along with CT scans [Fig. 3]. While the mechanism of injury of these fractures may vary, it is generally hypothesized that these fractures arise either from “buckling” forces in which the force to the orbital rim is transmitted to the orbital floor, or from “hydraulic” forces in which the force to the globe is transmitted to the orbital floor. Children in particular are at risk for entrapment of the inferior rectus muscle in orbital floor fractures owing to the
increased flexibility of their bones. The softer, more elastic bones allow the orbital floor to crack and snap back into place, thus forming a “trapdoor” in which orbital fat or the inferior rectus muscle may become entrapped.9,13 The longer this tissue remains entrapped, the greater the risk of ischemia and muscle damage leading to fibrosis and extraocular motility restriction.8,9,11

Studies have suggested that ischemia to skeletal muscle can lead to damage and fibrosis.10–12 Blaisdell10 highlighted that irreversible muscle cell damage in skeletal muscle of the limbs starts after 3 hours of ischemia and is nearly complete after 6 hours. Prolonged ischemia led to increasing vascular permeability and worsening interstitial edema as cellular death progressed.10,11 While different tissues exhibit varying degrees of tolerance to ischemia,9 similar principles may also apply to extraocular muscles.12 Orthopedic surgeons have noted Volkmann ischemic contractures as sequela of ischemia to the muscles of the limbs wherein there are limitations in mobility due to increased fibrosis.12 It was postulated by Smith et al.12 that a similar process may occur following blowout fractures of the orbit. These data, combined with various observational retrospective studies, led to the generally recognized recommendation that pediatric floor fractures with evidence of entrapment be repaired within 1 to 5 days and preferably within 48 hours, although there have been no prospective randomized trial to determine the optimal timing of surgical intervention.2,13,14 Typical indications for surgery include oculocardiac reflex, early enophthalmos or hypoglobus, or evidence of inferior rectus entrapment.

We had hypothesized that immediate repair within 24 hours would result in optimal resolution of motility deficits; however, data from our retrospective study show that there was no statistically significant difference in the resolution of vertical motility deficits. There were some notable trends. A greater proportion of patients who had surgery within 24 hours had fully recovered at the first and final postoperative endpoints. Furthermore, the Kaplan-Meier plot demonstrated an increased likelihood of recovery of motility deficits if the patient received surgery within 24 hours. In addition, 1 patient who underwent surgery after 24 hours from the time of injury ultimately required additional strabismus surgery for residual intolerable motility deficits. While not statistically significant due to a limited sample size, this improvement in full recovery rate and hazard ratio is clinically significant, and this trend supports current literature that timely repair is important.
This preliminary study could also help guide future studies. Sample size analysis, under the assumption that 90% of patients undergoing surgery within 24 hours and 75% of patients undergoing surgery after 24 hours achieve complete recovery, at alpha 0.05 significance, suggests that a future study would need to include approximately 97 patients in each group to achieve a power of 80%. Such a collaborative effort among oculoplastic surgeons serving a few large children’s hospitals could certainly be undertaken for a powerful analysis.

There were several limitations to this study. Patient charts were collected using ICD-9 diagnosis codes as inclusion criteria. While we attempted to capture the largest pool of patients by including various codes that may have captured orbital floor fractures, this method may have introduced bias into the study as the integrity of the data and results depends on the validity of the coding process. Another potential source of bias includes the requirement that patients have at least 1 follow-up appointment with the ophthalmology department at our institution. Several different surgeons from ophthalmology, otolaryngology, and facial plastics services may have operated on the patients in this study, and it is possible that patients may have followed up with different ophthalmologists not included in this study. The exact nature of the fracture and severity of injury may also be potential confounders in this study, as including all the injury categories into the statistical model was not possible given the data size. The study was limited to patients who underwent floor fracture repair without other concomitant facial fracture repair in an effort to reduce the potential confounding effects from the severity of various injuries. Furthermore, a hypothetical unobserved binary confounder with a 20% prevalence difference between those who undergo surgery within 24 hours and those after 24 hours would need to have a hazard ratio of 4 to tip the exposure effect from beneficial to harmful. Another inherent limitation in this study is the documentation of the motility deficits as an outcome measure as it is possible that patients recovered from their motility deficits prior to or soon after a scheduled appointment. We addressed this limitation by using survival analysis for interval censoring assuming the complete recovery, if it occurred, happened uniformly in the interval between the 2 visits. This assumption cannot be validated using the available data.

The data point to important trends that suggest that children have improved motility outcomes with earlier recognition and intervention. Although limited by a small sample size, this exploratory analysis supports the current literature that children promptly undergo surgical reduction of orbital floor fractures with evidence of inferior rectus entrapment.

REFERENCES